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PRESIDENTIAL ADDRESS *

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The Presidential Address is really "a pig in a poke", since it bears no warning title for its audience and the by-laws and tradition impose no limits on its author. Like the Walrus in *Alice in Wonderland*, I could "talk of many things; of shoes and ships and sealing wax, of cabbages, and kings". In fact I have given consideration to all those subjects and many others in the past couple of years since the Quebec Meeting.

Being a bone carpenter or joiner, however, I found my thoughts turning more and more to joints, and thence to the great diagnostic and therapeutic problem of arthritis which has fascinated me for years. It seemed in its mocking way to offer as elusive and intriguing a subject as one could desire. I use the term "arthritis" as it is used by the educated laity, the "rheumatism" of its less pretentious victims, and the "misery" of the old-fashioned negro who used simple and graphic terms. Within that term are included all painful, swollen, stiff joints, single or multiple, the cause and etiology of which are as yet unknown. Only excluded are the traumatic, tuberculous, septic, syphilitic, gonorrhoeal, and other arthritides in which the etiology has been basically proved. That definition certainly gives me as much latitude for discussion as the Walrus gave the Carpenter, and yet states as clearly as possible the subject of my address.

Naturally you will ask with raised eyebrows, "Who is this to be talking on arthritis?" Certainly I have not written much on the subject and for that I am right now duly thankful. My one paper on non-specific arthritis was read to this organization in 1935, and was concerned with the subject chiefly as a teaching problem[11]. In it (Table I), I endeavored to illustrate my conception of the arthritis enigma as a multicolored spectrum, including all the imperceptible variations between acute rheumatic fever and gout. In that spectrum one could not illustrate, however, the sometimes kaleidoscopic changes seen in a single case as it progressed from start to finish. I have found this simile useful, both in my teaching and to myself, in trying to formulate my own observations and ideas in a reasonable pattern. It was not a classification, not a hypothesis, but a sort of intellectual colorimetric scale.

My next contribution, and I am the first to admit that in itself it was a minor one, came in 1943, when Dr. John Lyford, III, and Dr. Roger Scott of the Hopkins Hospital Staff and I were able to split off from the general mass and identify etiologically a small, but interesting, group of infectious polyarthritis cases. We found these were due to an intracellular "Donovan body", causing more commonly the local venereal disease of granuloma inguinale. In these swollen, painful, and symmetrically involved joints, ordinarily easily classified as severe rheumatoid arthritis, we found and cultured *in vitro* (tissue cultures) this intracellular organism, and showed that it coexisted in other organs too, causing a disseminated and fatal disease.

This totally new type of organism, found as the cause of a "rheumatoid polyarthritis", whetted our curiosity and hopes. In the past four years I have spent much of my time

* Read at the Annual Meeting of The American Orthopaedic Association, Virginia Beach, Virginia, May 25, 1950.

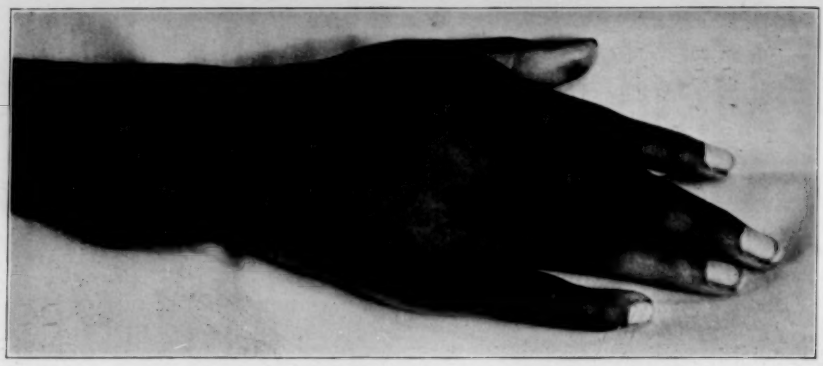

FIG. 1

Right hand of patient with granuloma inguinale, showing the characteristic swelling of chronic arthritis in wrist and interphalangeal joints, of four months' duration. (Reproduced, by permission, from *American Journal of Syphilis, Gonorrhea, and Venereal Diseases*, 28: 591, 1944.)

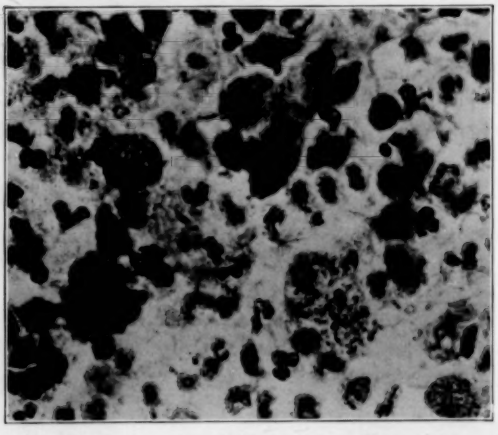

FIG. 2

Photomicrograph (× 1,500, Giemsa stain) of synovial membrane from elbow of case of granuloma inguinale. Many large cells are packed with Donovan bodies. (Reproduced, by permission, from *American Journal of Syphilis, Gonorrhea, and Venereal Diseases*, 28: 597, 1944.)

and other people's treasure* in a still hunt for similar intracellular organisms in the tissue sections and tissue cultures of biopsies from many kinds of cases of non-specific arthritis, both in adults and children, and have checked them against normal controls.

I wish I had something definite and dramatic to report and to show you in the slides I have brought to demonstrate this work. But thanks to my good friends, the hard-to-convince pathologists, I have been hauled back from getting myself out on any too fragile limbs of questionable intracellular microbacteriology. All I can surely find in tissue cultures of the normal and rheumatoid synovial membrane are similar and apparently healthy outgrowths of fibroblasts, sometimes associated with a halo of normal-appearing wandering cells about the Medusa-like fibroblastic fringe. A careful search of these cellular outgrowths under oil immersion revealed occasional irregularities and granules, indefinite and inconstant inclusion bodies, and vacuoles which kept me on the *qui vive;* but so far the light microscope and regular staining techniques have failed to show any definite "foreign agents" lurking therein. I present these negative findings in order that this laborious, if fascinating, work need not be repeated unless new techniques, such as the use of the electron microscope, are tried. If selective stains of microbacteria, viruses, or enzymes are developed in other fields, they also could be applied to this problem afresh.

My failure to find a specific cause for at least some of these arthritides, though disappointing, was probably my very good fortune. For the experimental pathologists

* The research herein reported was carried on at the Children's Hospital School, Baltimore, and was financed at first by a substantial gift from Mrs. John Work Garrett and later pursued with funds from The Louise Cunningham Bowles Research Fund.

and biochemists have shed much new light recently on the basic problem of arthritis by demonstrating that pure anaphylactic sensitivity will produce lesions similar to arthritis in animals, and that the clinical response of human arthritics to ACTH and cortisone parallels that of many other known hypersensitive reactions. It would seem that not only are the rheumatic diseases, from acute rheumatic fever up, probably just variations of a

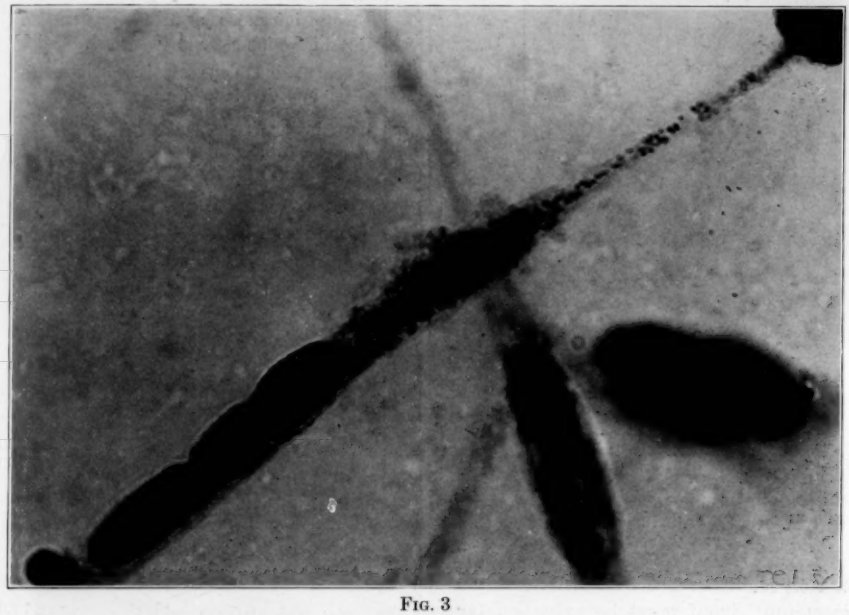

FIG. 3

Photomicrograph (× 1,200, Giemsa stain), showing fibroblast packed with Donovan bodies. Tissue culture of synovial membrane from case of granuloma inguinale. (Reproduced, by permission, from *American Journal of Syphilis, Gonorrhea, and Venereal Diseases*, 28: 599, 1944.)

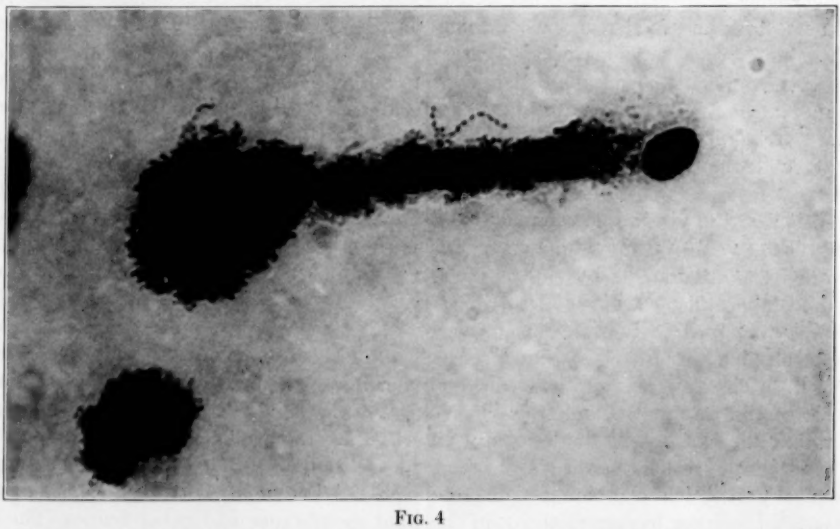

FIG. 4

Photomicrograph (× 1,200, Giemsa stain) of tissue culture showing macrophage with Donovan bodies escaping into media in case of granuloma inguinale. (Reproduced, by permission, from *American Journal of Syphilis, Gonorrhea, and Venereal Diseases*, 28: 599, 1944.)

TABLE I
A GRAPHIC METHOD OF CLASSIFYING THE ARTHRITIDES

Clinical Manifestations	Spectrum	Type of Arthritis
	Infra-Red	
No resultant joint change	Red	Acute rheumatic fever
Joint changes of proliferative type		Acute infectious arthritis—relation to focal infection clear
	Orange	Subacute infectious arthritis—relation to focal infection indefinite
		Still's disease
	Yellow	Rheumatoid arthritis
Atrophy		Atrophic arthritis
		Arthritis deformans
Mixed changes	Green	Villous arthritis
		Serum or allergic arthritis
		Arthritis associated with endocrine disturbances
	Blue	Arthritis associated with chronic traumatization
Degenerative type of joint lesion		Marie-Strümpell arthritis
		Hypertrophic arthritis
Crystalline deposits	Violet	Osteo-arthritis
		Gout

(Reprinted from *The Journal of Bone and Joint Surgery*, 18: 868, Oct. 1936.)

common reaction, as I unwittingly implied in my spectrum schema of 1935, but also the "spectrum" itself must be extended far out on both the infra-red and the ultraviolet ends to include a host of other hypersensitivity states. Henceforth in our thinking and experimental approach, we must not deal with non-specific arthritis alone as an entity, but consider it in relation to other hypersensitivity conditions, in common with serum sickness, drug and food reactions, asthma, hay fever, periarteritis nodosa, sympathetic ophthalmia, lupus erythematosus, et cetera.

One has long believed in *an* allergic group in the arthritides. In fact, my father wrote a paper in 1912 on "The Tomato Joint",[10] a form of arthritis he suffered each early autumn from overindulgence in fresh, ripe tomatoes from his garden. But it has been hard to conceive that most non-specific arthritis could be on a pure hypersensitivity basis, for the great conquests of disease instituted by Pasteur, Koch, and Lister have focused our attention on the vital importance of bacteria locally as the cause of disease. Now suddenly it becomes of utmost importance for us to try to reorient our thinking to the discoveries presented to us by the recent advances in endocrinology, biochemistry, and kindred laboratory sciences and to the implications and possibilities they contain. For example, the apparently irrelevant discovery that a virus (of the tobacco-mosaic disease) can be obtained in pure crystalline form has truly vast implications. For this virus would seem to bridge the great gap between the living cell of the old "germ-theory" days and the large complex molecule of this biochemical era. It is not beyond our consideration now that the excitant of the lesions of arthritis may be a nucleoprotein molecule or a polysaccharide, rather than a viable organism. Or it could be even a very much simpler chemical unit which, combining with protein provided from the host's tissues, acts as an antigen to incite a hypersensitivity in the joint membranes and other tissues. The explorer searching for the cause of arthritis has indeed left the tight little island of bacteriology and stands on the edge of a vast sea where pH's, viruses, enzymes, toxins, vitamins,

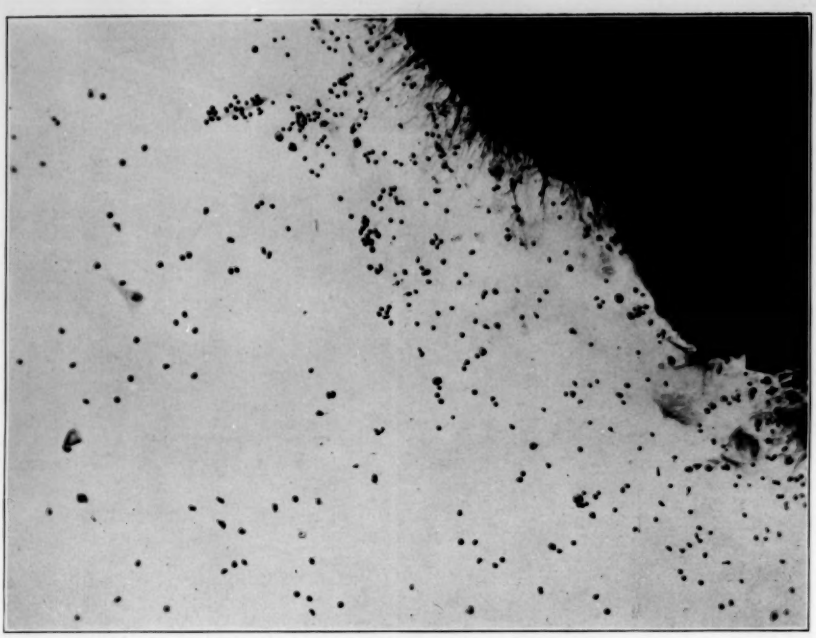

FIG. 5

Photomicrograph (× 110, Giemsa stain) of tissue culture of synovial membrane in case of rheumatoid arthritis, after three days. There is a Medusa-like outgrowth of fibroblasts with halo of wandering cells in media.

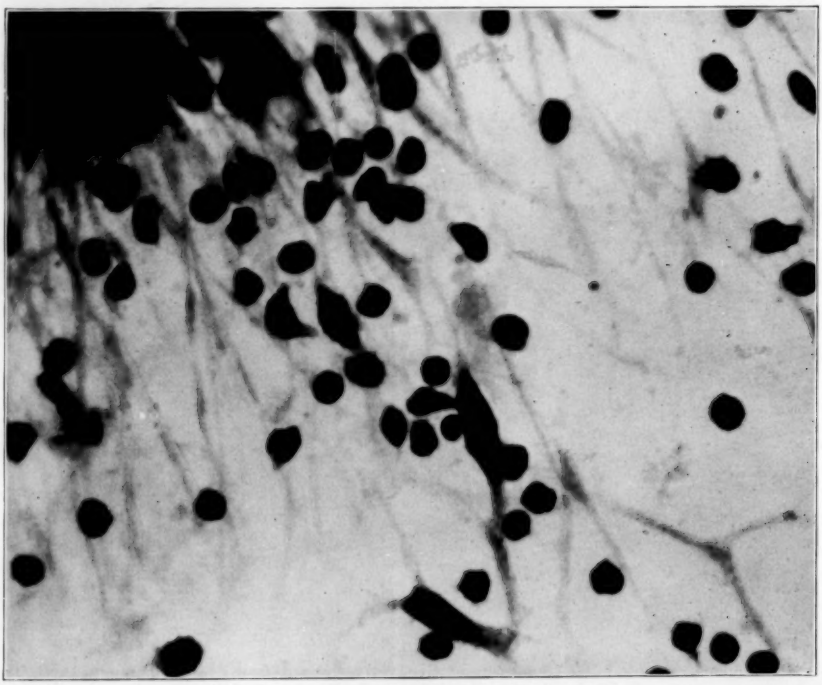

FIG. 6

Photomicrograph (× 1,100, Giemsa stain). Fibroblasts and wandering cells from tissue culture of synovial membrane in case of rheumatoid arthritis.

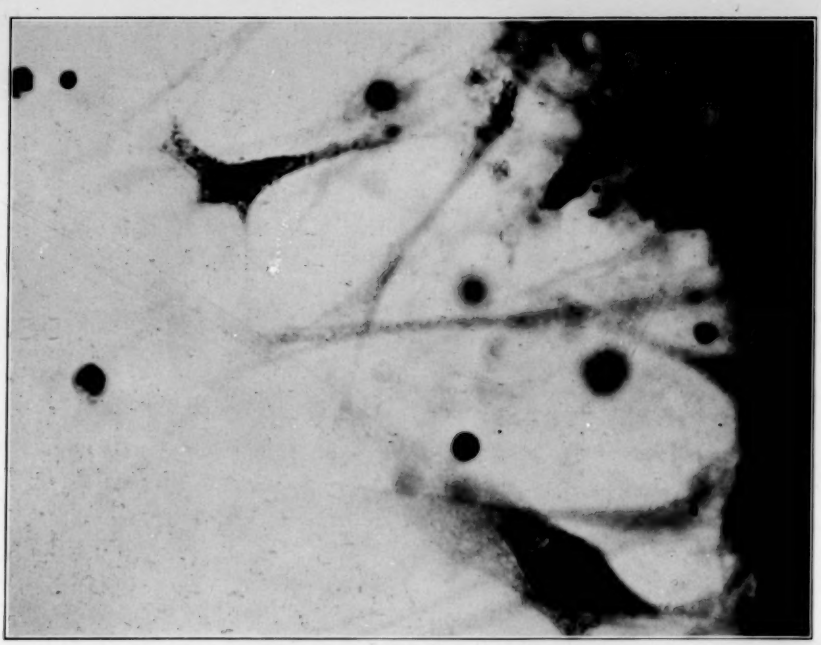

FIG. 7

Photomicrograph (× 1,100, Giemsa stain). Fibroblast with inclusion bodies which excited suspicion, but were too inconstantly present to be identified. Tissue culture of rheumatoid synovial membrane.

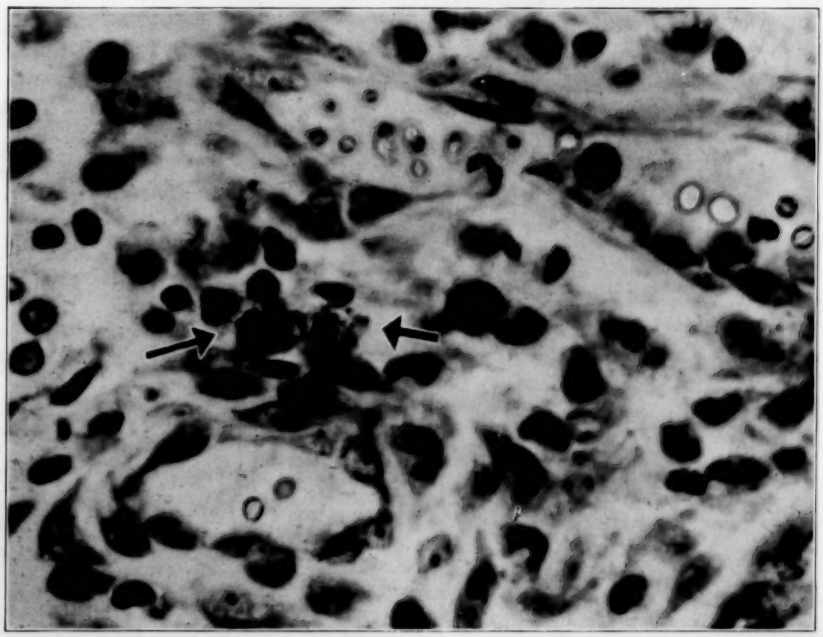

FIG. 8

Photomicrograph (× 1,100, Giemsa stain). Synovial membrane from case of rheumatoid arthritis showing two large cells filled with suspicious inclusion bodies, a not infrequent observation. Bodies, however, could not be definitely identified to the satisfaction of the pathologists.

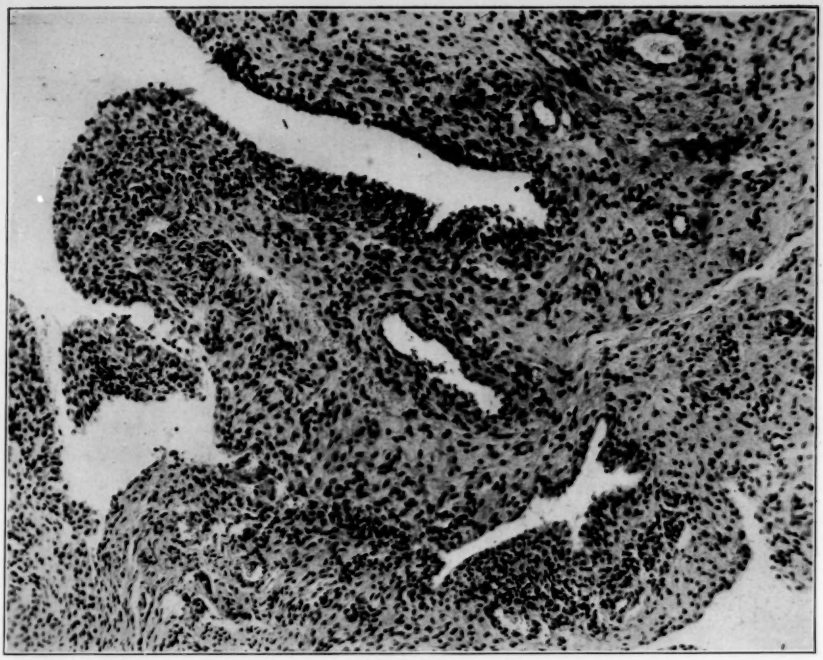

FIG. 9-A

Photomicrograph (× 110, hematoxylin and eosin stain). Case J. B. Synovial membrane from biopsy specimen before any cortisone therapy. Note cellular pattern of villous synovial membrane.

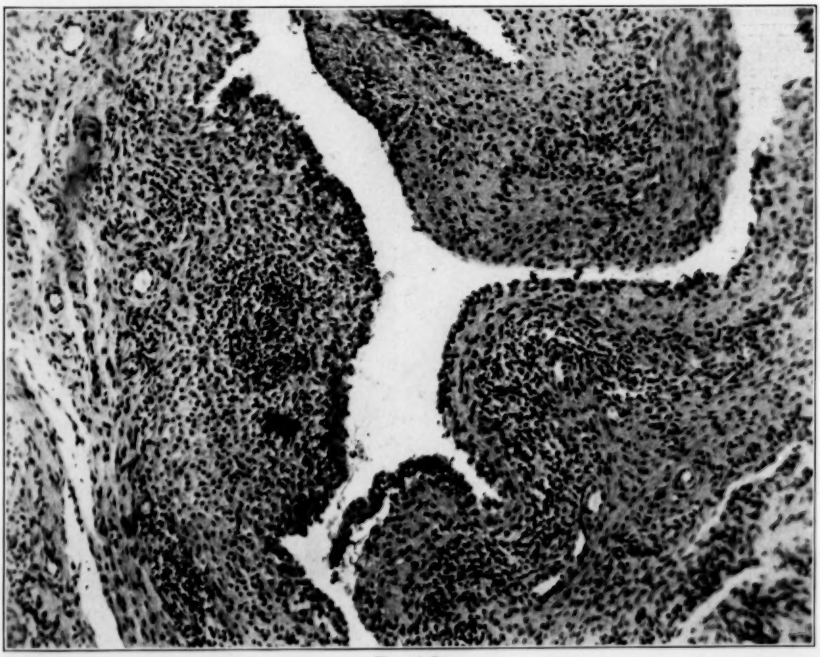

FIG. 9-B

Photomicrograph (× 110, hematoxylin and eosin stain). Synovial membrane from biopsy specimen taken in mid-treatment (after three weeks of daily 50-milligram doses of cortisone in child of nine years). No appreciable change in cellular reactions.

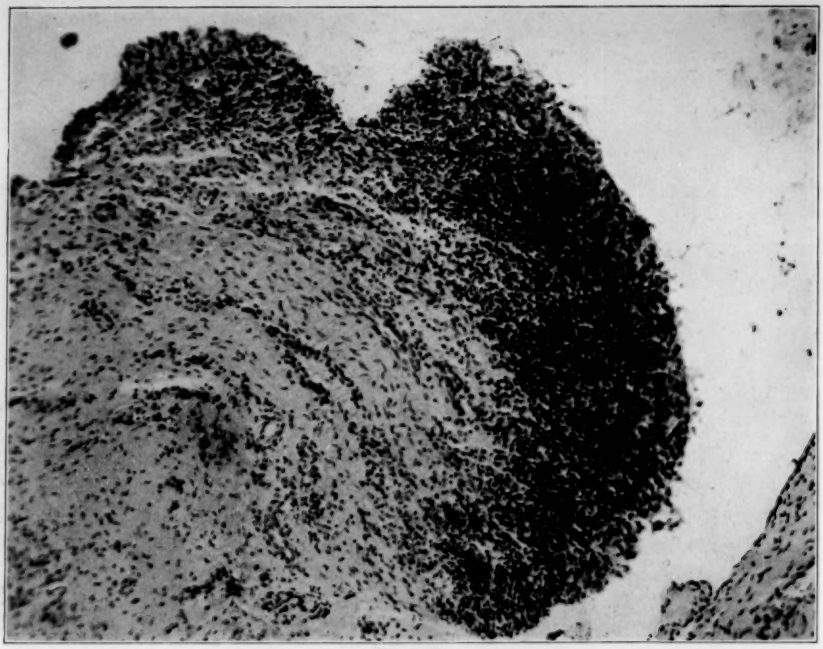

FIG. 9-C

Photomicrograph (× 110, hematoxylin and eosin stain). Synovial membrane from biopsy specimen at end of six weeks of cortisone treatment. Cellular pattern shows no regression toward normal picture. Patient was and continued to be much improved symptomatically.

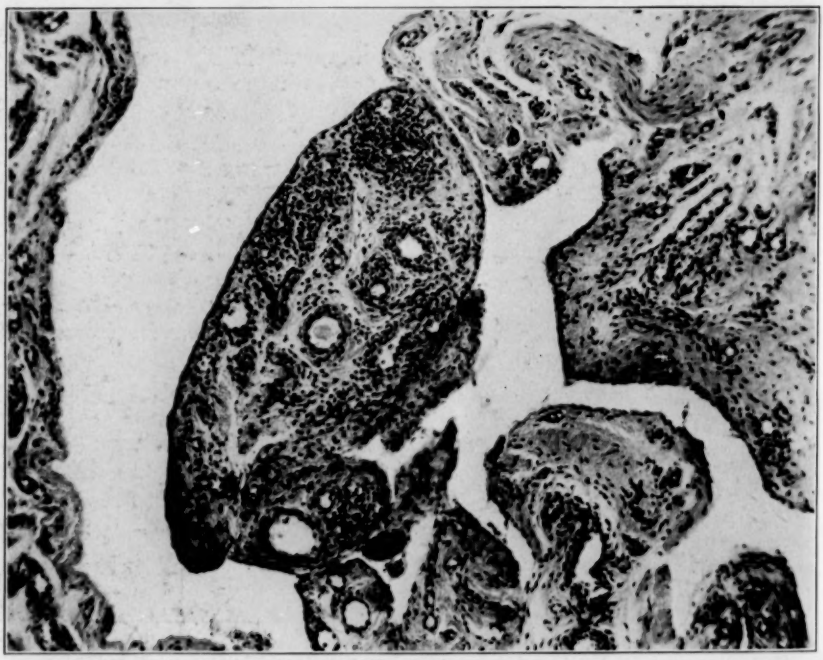

FIG. 10-A

Photomicrograph (× 110, hematoxylin and eosin stain). Case C. H. Synovial membrane from biopsy specimen before treatment. Note basic cellular pattern.

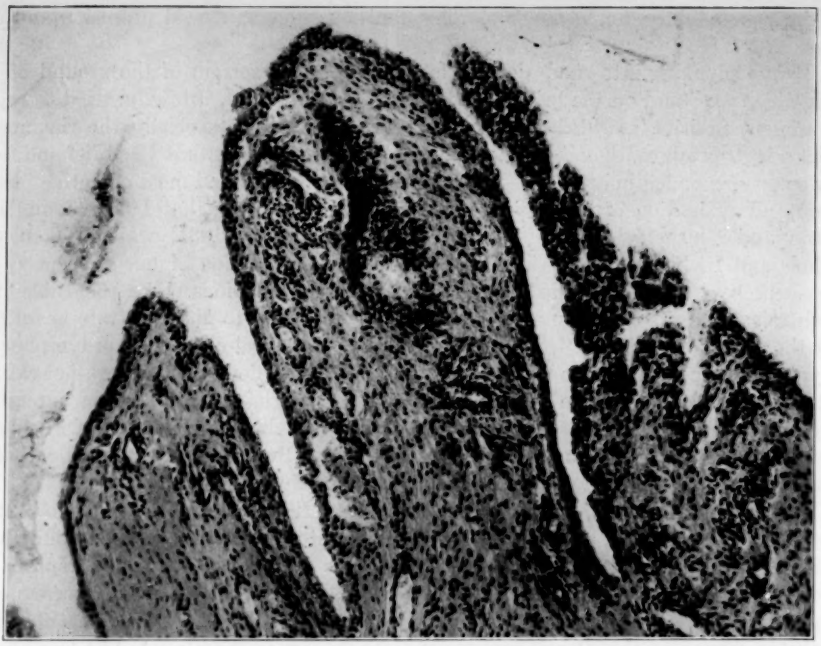

FIG. 10-B

Photomicrograph (× 110, hematoxylin and eosin stain). Synovial membrane from biopsy specimen after ten days of cortisone treatment (100 milligrams daily). Villi are prominent, surface layer hyperplastic, and lymphoid collections unchanged.

FIG. 10-C

Photomicrograph (× 110, hematoxylin and eosin stain). Synovial membrane from biopsy specimen at end of three weeks of cortisone treatment. Perivascular infiltration and lymphoid nodules are unchanged. Synovial surface layer is still hyperplastic.

antigens, metabolites, hormones, molecules, and ions mingle in wild profusion and confusion as yet.

Before plunging into these depths, let us at least be certain of the ground of fact upon which we stand on the brink. To do this I have honestly, if briefly, tried to review our present positive knowledge. The literature on arthritis, especially the rheumatoid variety, is stupendous, though often rather vague. Time requires that I be brief and select only some of the high points for comment. By far the clearest and most objective presentation and evaluation of the basic knowledge of its pathology that I have found is in Allison and Ghormley's book, *Diagnosis in Joint Disease* (1931) which, taken with Nichols and Richardson's classic of 1909, forms the foundation of our concept of the disease process as distinguished from its clinical manifestations. Like the Bible, it is worth rereading often. Allison and Ghormley call attention to and illustrate beautifully that the essential lesions of "proliferative arthritis" are focal collections of lymphocytes in typical arrangement (Plate VIII of their text). They also demonstrate the other variable features of thickening of the surface synovial layer, plasma-cell infiltration, interstitial fibrosis, profusion of dilated vessels, et cetera. The valuable contributions of Phemister, Key, Bauer, Ropes, and Waine, Fisher, Strangeway and Burt, and others to the pathology of arthritis must be passed over, but not without grateful acknowledgment.

Rosenow, Pemberton, Cecil and his associates, Burbank and Hadjopoulos, and a host of others, including, alas, myself, have delved into the bacterial etiology of arthritis with inconclusive results. Streptococci of various hues, diphtheroids, streptobacilli, L-forms, and intracellular inclusion bodies have all been suspected and not infrequently adjudged guilty, only to escape on appeal and leave the crime still unsolved. I think the credit for suggesting the allergic concept of arthritis goes to Weintraud, who first applied it to acute rheumatic fever in 1913. Rich, however, using his experience in the sensitivity reactions to foreign protein, put the allergic cause on a secure scientific basis by showing that lesions comparable to those of rheumatic fever and periarteritis nodosa could be produced by purely non-bacterial antigens in a sensitized animal, and that similar fresh lesions also are found in human autopsies in case of drug hypersensitivity.

Long years of hormone research, in which our guest, Dr. Selye[23, 24], has played a large part, have established the importance of this host mechanism in arthritis. It is impossible to express too great appreciation of the labors of the endocrinologists and biochemists, especially the brilliant collaboration of Dr. Kendall and Dr. Hench[7–9] in giving us cortisone (Compound E), that single definite chemical compound with miraculous if transient effect, relatively safe to use in considerable quantity for considerable time. ACTH and cortisone are our present finest and most valuable instruments in navigating the murk of variables which obscures the true nature of the disease we are seeking to discover.

At this mid-century point we, therefore, possess:

1. The realization that non-specific arthritis does not stand alone, but belongs to the mysterious and protean group of collagen diseases, and that discoveries in the kindred fields of asthma, lupus erythematosus, psoriasis, et cetera, will shed light on our problem as well.

2. The picture of a definite inflammatory pathological lesion to observe and check against in human cases.

3. A laboratory means of producing this lesion by non-bacterial antigens in the sensitized animal.

4. Hormone substances which seem to reduce or eliminate the hypersensitivity reaction.

Much can be done with these known factors in steering a way into the unknown.

I want to report briefly the early findings in a small investigation I have in progress since I became the proud possessor of a few grams of cortisone in January. It covers but three subacute chronic rheumatoid cases—one child, one man, one woman. We have not

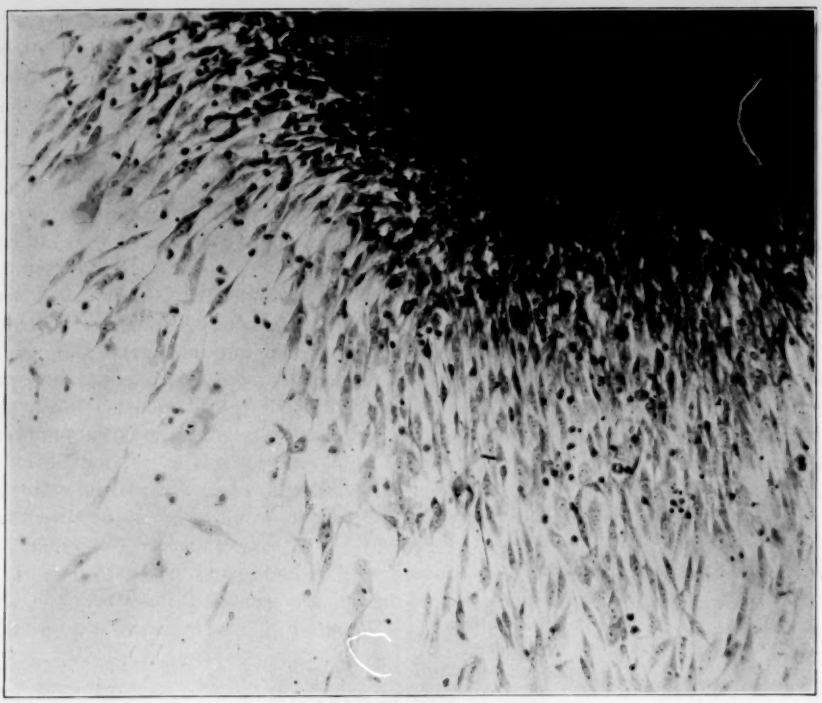

FIG. 11

Photomicrograph (× 110, Giemsa stain). Tissue culture of synovial membrane (four days old) from pre-treatment biopsy specimen. Excellent outgrowth of fibroblasts and some wandering cells.

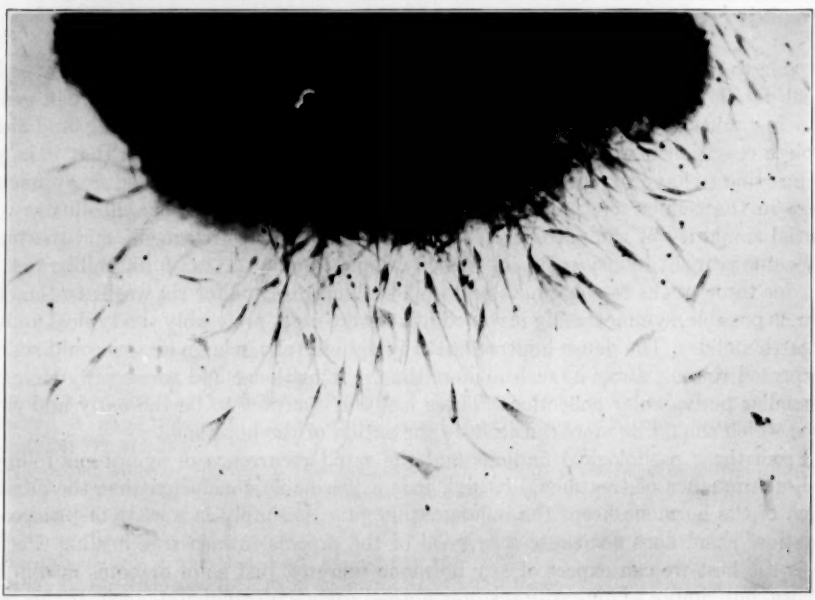

FIG. 12

Photomicrograph (× 110, Giemsa stain). Tissue-culture synovial membrane (two days old) from mid-treatment biopsy specimen. Excellent outgrowth of fibroblasts for such a young culture; compares favorably with pre-treatment and post-treatment cultures which are older.

FIG. 13

Photomicrograph (× 110, Giemsa stain). Tissue-culture synovial membrane (four days old) from biopsy specimen at end of treatment. Excellent outgrowth of fibroblasts and wandering cells. No sign that cortisone therapy alters potential of growth of cells after transplantation to regular media.

been able to get our hands on a suitable case of Still's disease as yet. I will not go into clinical details, but report only that each case showed definite improvement in general well-being, much increased mobility in affected joints, diminution of swelling, and almost complete cessation of pain. In fact the clinical response was so magical that it is most disconcerting to have to report that biopsies of the swollen joints revealed no appreciable change in the cellular picture. The accompanying photomicrographs will illustrate the essential similarity of the pathological pictures shown in pre-treatment, mid-treatment, and post-treatment biopsy material. The cortisone in daily doses of 100 milligrams was given for three weeks to the adults and in 50-milligram doses for six weeks to the child. As far as possible, symmetrically involved joints were used, preferably the typical multiple Haygarth's nodes. The dense infiltrations of lymphoid cells in large masses could scarcely be expected to melt away in such a short time, but neither could we see any change in the smaller perivascular collections. These latter I interpret to be the early and active lesions which should be more sensitive to the action of the hormone.

From these pathological findings and the rapid recurrence of symptoms following the discontinuance of treatment, I think it is a justifiable conclusion that the administration of the hormone keeps the inflammatory process simply in a state of "suspended animation", and does not cause a reversal of the process toward true healing. Perhaps that is the best we can expect of any hormone therapy, just as in diabetes insulin does not cure, but simply temporarily restores normal carbohydrate metabolism. If this be so, we certainly do not have in cortisone the type of *cure* for arthritis that we have been hoping for.

Inasmuch as these investigations of mine are very few in number and short in duration by necessity, and the findings on the pathological changes are as inconclusive as those being reported from many other sources[3, 15], it is evident that progress to date is practically nil and that arthritis and its X-factor remain as elusive and intriguing as ever. It is a tremendously exciting, a tremendously important quest. There is no group with more clinical experience in arthritis than ours, and I regret the fact that the medical man and the laboratory investigator seem to have outstripped us in both interest and effort in attacking the problem. Orthopaedic surgery has of late seemed to emphasize too much its surgical side and to have lost some of its concern for and interest in the medical and metabolic aspects of crippling disease, which are certainly among our primary obligations. Let us rise, therefore, and bestir ourselves in this direction by clinical cooperation and continued investigation before it is too late to share in the conquest of such a grievous malady. We have done much to improve the methods of treatment of traumatic and congenital lesions, scoliosis, et cetera, but meanwhile the victory over rickets, the control of pyogenic osteomyelitis and of tuberculosis, have come to us without our having had a glorious part in the investigations which developed them. This time let us meet the challenge of arthritis and its associated collagen diseases; for certainly, as orthopaedic surgeons who are dedicated to the study and care of skeletal conditions, we have a primary interest in and knowledge of mesenchymal tissue and that now very important organism, the connective-tissue cell.

Lewis Carroll, in that Looking-Glass Wonderland of Alice's, often held up the mirror of his whimsical satire to very real human foibles and frailties; so, in closing, I will use a quotation of his as a warning to us all:

"The Walrus and the Carpenter
Were walking close at hand;
They wept like anything to see
Such quantities of sand:
'If this were only cleared away',
They said, 'it would be grand'!

'If seven maids with seven mops
Swept it for half a year,
Do you suppose,' the Walrus said,
'That they could get it clear?'
'I doubt it,' said the Carpenter,
And shed a bitter tear."

Let us be sure that this picture of woeful futility and detached irresponsibility is not that which we present today to the eyes of the Medical World.

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FLEXOR-TENDON GRAFTS IN THE FINGERS AND THUMB

An Evaluation of End Results *

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Reconstruction of the flexor-tendon mechanism in digits is most difficult in the area lying between the distal crease of the palm and the middle flexion creases of the fingers (Fig. 1). In this critical zone, so aptly called "no-man's land" by Bunnell, both flexor tendons pass through the fibrous tunnels or pulleys; any scarring from injury, infection, or previous surgery impairs the gliding motion of the tendon and restricts the flexion of the digits. In order to flex the interphalangeal joints of the finger completely, the deep flexor tendon must make an excursion of three-fourths of an inch in the proximal segment of the finger and one and three-eighths inches in the palm [2]. If this excursion is limited, the tip of the finger fails to touch the distal crease of the palm. The measurement of this distance, *the lack of flexion to the distal crease*, thus becomes an easily recorded and readily

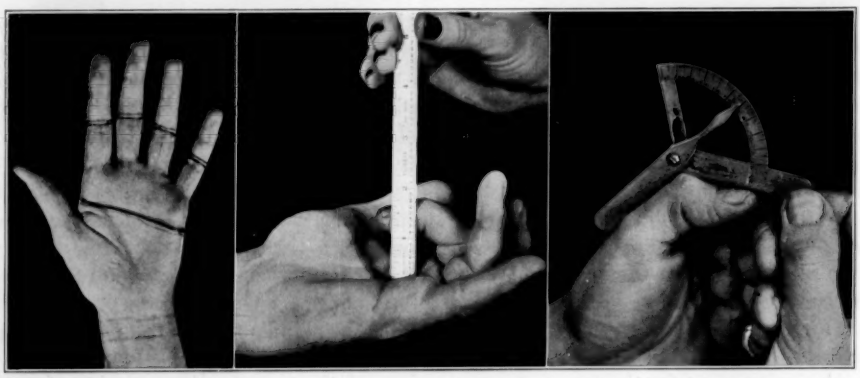

FIG. 1 FIG. 2 FIG. 3

Fig. 1: Flexor-tendon damage in the area marked, the critical zone of "no-man's land", is common; repair is difficult and reconstruction by free grafts is often necessary. All cases in this series had damage to tendons in this area. (Reproduced, by permission, from *Annals of Western Medicine and Surgery*, 1: 145, 1947.)

Fig. 2: The measurement of flexor-tendon function in a finger, an easily made and readily understood index of function following repair or reconstruction. Here the pulp of the long finger lacks one inch of reaching the distal crease of the palm.

Fig. 3: Function of the long flexor tendon of the thumb is measured by the degrees of flexion of the interphalangeal joint.

understood index of the results of flexor-tendon action in the fingers (Fig. 2). In the thumb, the long flexor tendon acts primarily on the interphalangeal joint. Flexion here is best measured in degrees of the arc which the tip of the thumb makes from a line parallel to the proximal phalanx. Its percentage of motion is determined by comparison with the range of passive motion in the same joint (Fig. 3).

This study is limited to cases involving damage to flexor tendons in the "critical" zone[1], since reconstruction in this area offers the most rigid test of operative technique. A total of 138 grafts were used in 118 patients. Twenty-three of these were in the thumb, forty-three in the index finger, twenty-nine in the long finger, thirteen in the ring finger, and thirty in the little finger. Multiple tendon reconstructions were done in eleven patients:

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 15, 1950.

CHART I

Age affects the end results of flexor-tendon grafting in the fingers only in the very young, where there is lack of cooperation in the after-care.

the thumb and index finger together twice; the thumb and long finger once; the index finger and long finger five times; the index finger and ring finger once; the index finger, long finger, and ring finger once; and all four fingers once. The end results are known in all but thirteen cases. Therefore, the final figures are based upon a study of 104 flexor-tendon grafts in the fingers and twenty-one flexor-tendon grafts in the thumb.

The basic technique used throughout this study was that described by Bunnell,—namely, a full-length tendon graft extending from the lumbricalis origin in the palm to the terminal phalanx of the digit; the distal attachment was tendon-to-bone, the proximal suture being in the palm, inserted according to the Bunnell technique. Pulleys were reconstructed at the metacarpal heads by free graft when necessary, and the pulley mechanisms in the fingers were restored by suture of the deeper tissues. To provide material for the graft, either the proximal portion of the sublimis tendon from the involved digit was used, or the palmaris longus tendon from the forearm. In a few instances it was necessary to take the long extensor tendons of the toes. In the majority of cases, digital-nerve damage accompanied the tendon injury; whenever possible, this was repaired at the time of the tendon operation.

An evaluation of the end results of flexor-tendon reconstruction must take into consideration the preoperative condition of the hand. Three major factors influence the results: scar tissue, stiff joints, and trophic changes from nerve damage. The reconstruction of more than one digit at the same time usually impairs the result, and there are other factors which cannot be foretold, such as the individual's reaction to trauma and his willingness to work and exercise for a better result, in spite of some discomfort. Chart I shows the age groups involved in this study, and indicates that age in itself apparently does not influence the end results, except in the very young, where there is lack of cooperation in the after-care.

CLASSIFICATION OF CASES

In this study all cases were classified preoperatively into one of five groups, based upon the condition seen when the patient was first examined. In a few cases, preliminary operation was done to improve the function of the joint or to remove excessive or deforming scars. In many instances a period of slow, gradual, elastic traction was used to mobilize the joints before tendon reconstruction was attempted. The criteria used in classifying cases were as follows:

Good: This was the ideal group, with minimal scarring in the skin and soft tissues,

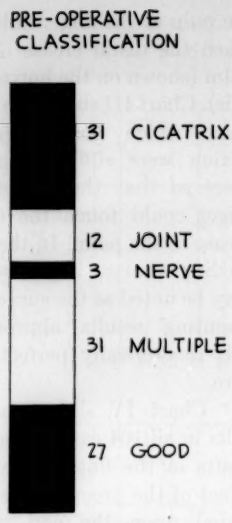

CHART II

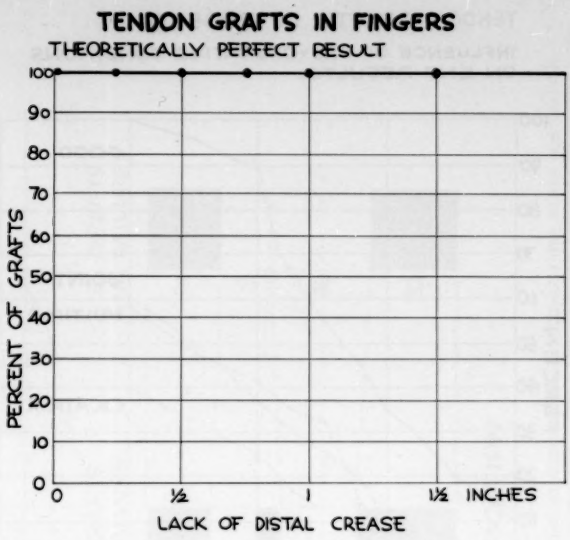

CHART III

Chart II: The relative proportion of cases having factors which influence the results of flexor-tendon grafting in the fingers, as seen in this series of 104 consecutive cases.

Chart III: Showing the ideal result which would occur if, in all cases in a series, flexion of the finger to the distal crease of the palm were possible after tendon-grafting.

good supple joints, no ligamentous or capsular contractures, and no major trophic changes from nerve damage. The loss of function of one or both of the digital nerves was not considered detrimental, and such cases were classed in this group unless trophic changes were severe.

Cicatrix: In this group were included cases in which there was scarring from the injury or from ill-advised mid-line incisions, or in which deep cicatrix followed infection from attempted primary repair. The contractures resulted from deep scar tissue rather than from joint stiffness. In a few instances a preliminary Z-plasty was done or a pedicle flap was applied to repair the soft-tissue damage before tendon reconstruction was carried out.

Joint Damage: Cases were classed in this group when the range of passive motion of an interphalangeal joint was restricted. A period of slow, gradual, elastic traction was carried out, and as much easy, free, passive motion as possible was obtained before the tendon was reconstructed.

Nerve Damage: This was a small group, limited to those cases in which damage to the major nerve trunks caused trophic changes in the fingers and resulted in smooth, shiny skin and secondary stiffness of the joints. In some instances the major nerve damage was repaired, and the tendon was reconstructed after regeneration had taken place.

Multiple Damage: Where tendon damage was not confined to one digit, an attempt was made to reconstruct all the damaged tendons at one operation. Many of these cases were complicated by other factors, such as cicatrix and joint stiffness. These were combined into one group.

The number and proportions of the 104 tendon grafts in the fingers in each classification are shown (Chart II).

RESULTS

The results of tendon grafts in the fingers are best presented graphically, the percentage of cases (shown on the vertical line) being plotted against the distance by which

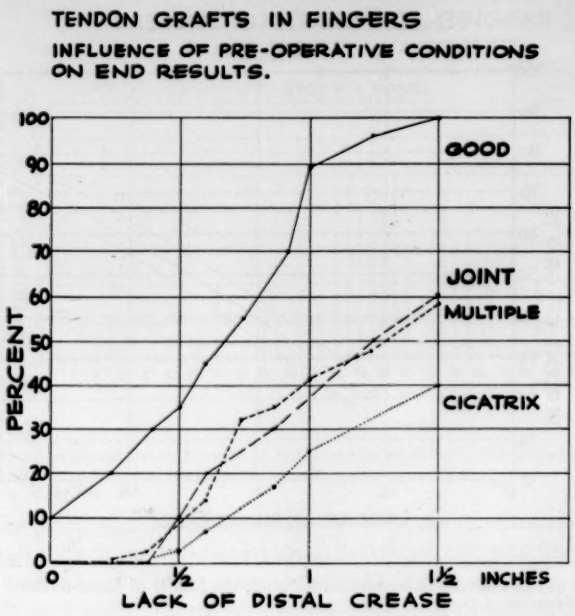

CHART IV

Illustrating the effect of preoperative factors on the end results. Whereas almost 90 per cent. of cases in the "good" group had flexion to within one inch of the distal crease, less than half of those having stiff joints and only one-quarter of the "cicatrix" group had such a good degree of flexion.

the pulp of the finger failed to reach the distal crease of the palm (shown on the horizontal axis). Chart III shows the ideal result which would occur if flexion were sufficient in all cases so that the tip of the finger could touch the distal crease of the palm. In the succeeding charts, improvement may be noted as the curve representing results approaches this theoretically perfect picture.

Chart IV shows the results in all 104 cases of tendon grafts in the fingers, and the effect of the preoperative condition upon the end result. Whereas in 10 per cent. of cases in the "good" classification, flexion was sufficient so that the pulp of the finger touched the distal crease of the palm, in not a single case in the other classifications was flexion possible to this complete degree. In the "cicatrix" group, the best result was flexion to one-half inch from the distal palmar crease, whereas in the group classified as "good", 35 per cent. had flexion to that degree and all patients had flexion to within one and one-half inches of the distal crease. In the "cicatrix" group, only 40 per cent. had flexion to within one and one-half inches of the distal crease in the palm; in the "multiple" group, 59 per cent.; and in the "joint" group, 60 per cent. The results in the "joint" cases approximate those in the "good" cases, because elastic traction and mobilization were carried out before tendon reconstruction was done. However, in these patients the same tendency for stiffness of the joints followed the operation as well as the injury; and, therefore, the end results are not so good as in the ideal group.

Chart V shows the effect on the end result of four variations in technique. In the first group, silk was used both at the suture line in the palm and at the distal insertion into the phalanx.

In the second group, silk was again used in the palm, but a Bunnell type of pull-out wire suture of stainless steel, passed through a drill hole in the terminal phalanx and tied to a button over the nail, was used at the insertion of the graft into the terminal phalanx. This wire was removed after three weeks. It can be seen from Chart V that there was relatively little difference in the end results. However, the classification in the lower portion of the chart shows that only 8 per cent. of the cases in this group were "good" as compared to 24.2 per cent. in the group in which only silk sutures were used. The greatest difference, however, is seen in the number of failures. There were seven failures in the silk series, all due to infection occurring around the silk, whereas there were only two failures in the second group, neither of which was due to complications at the insertion of the graft.

In the third group, stainless-steel wire was used throughout, both at the insertion

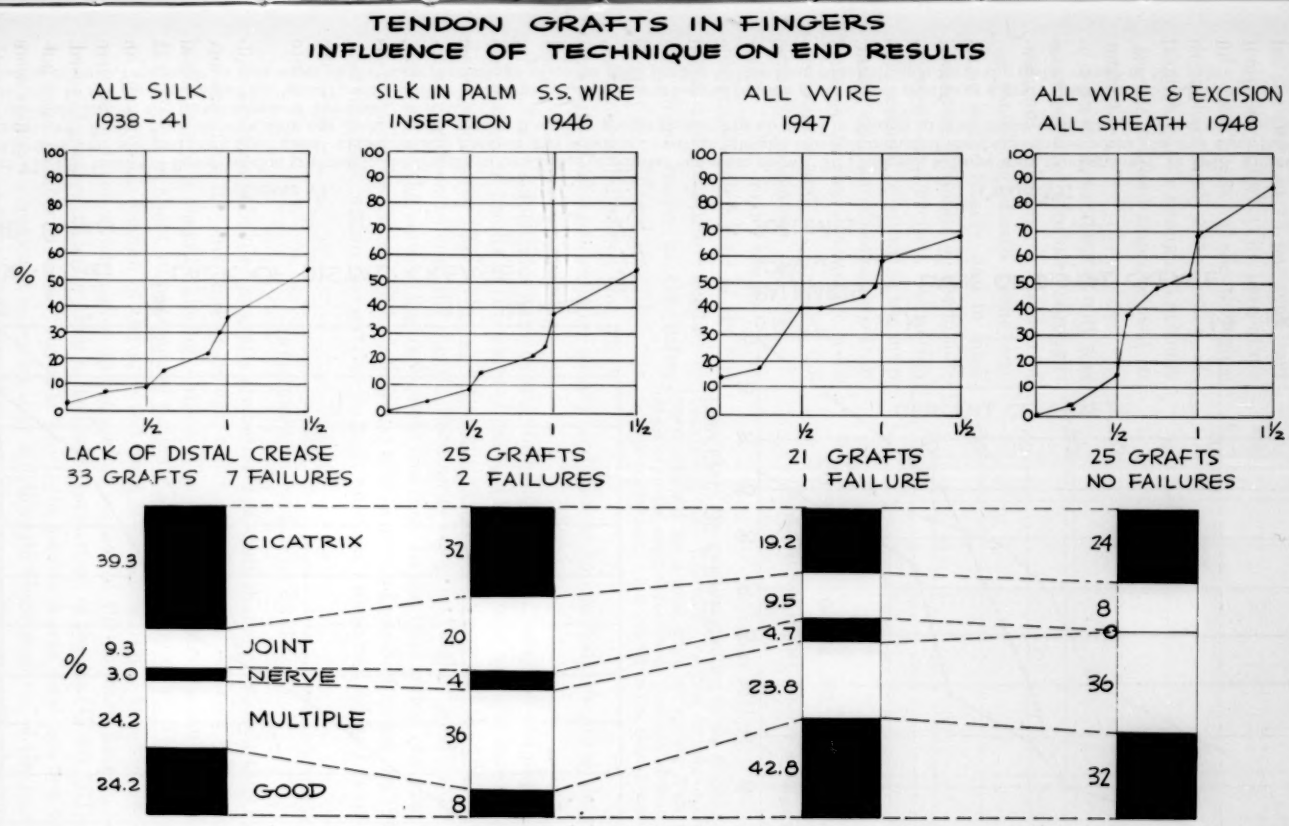

CHART V

Regardless of all other factors, the progressive increase in steepness of the curves of the four graphs indicates improvement in results due to the one variable,—technique. The large number of failures in the period from 1938 to 1941 were due to complications from the buried silk sutures; this difficulty had been overcome in the 1948 series. The lower bars illustrate in percentage the preoperative factors present in the various groups. (See Chart VI for the effect of technique on comparable classes.)

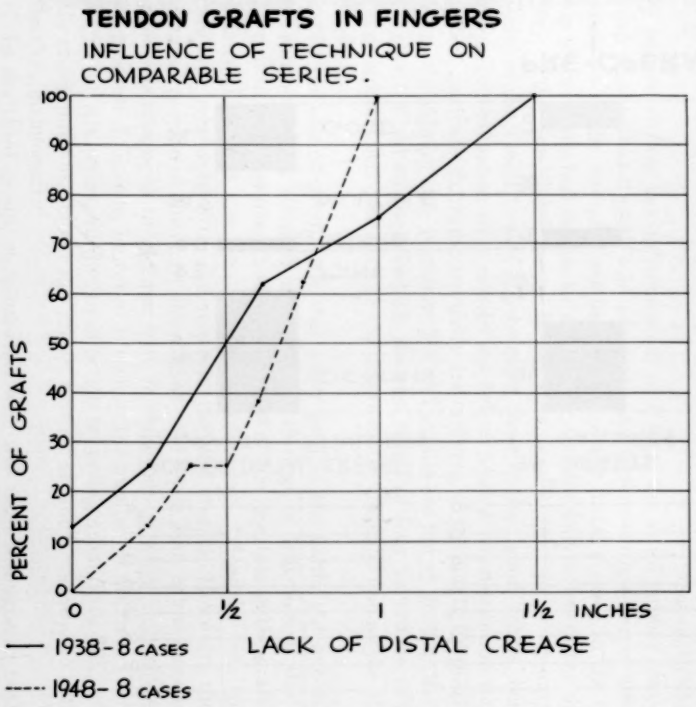

CHART VI

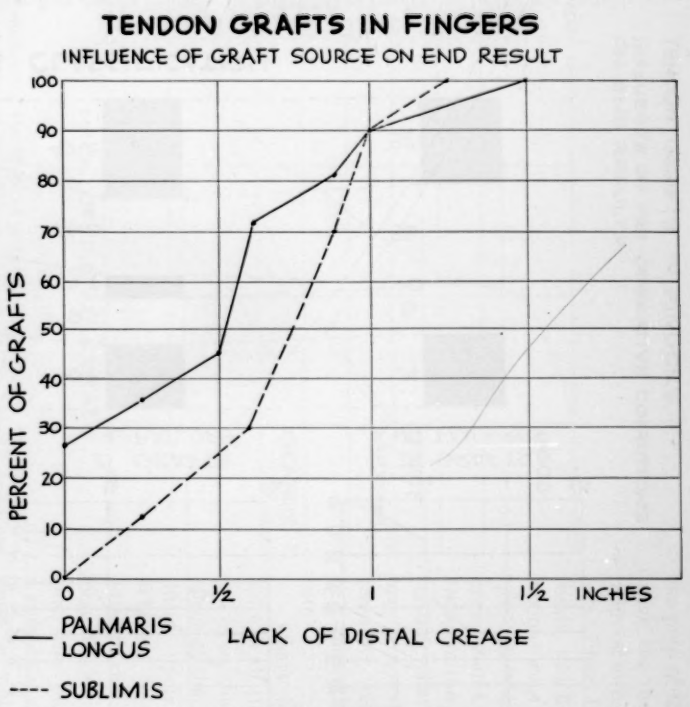

CHART VII

Chart VI: The results of flexor-tendon grafting in the fingers in two series of similar cases are shown: In 1938, silk sutures were used entirely; in 1948, wire was used in all. All cases were selected from the "good" classification. Flexion was possible to within one and one-half inches of the distal crease when silk was used, but in only 75 per cent. was flexion possible to within one inch. Use of wire in a similar group resulted in all cases in flexion to within one inch, and in 25 per cent. in flexion to within one-half inch of the distal crease of the palm.

Chart VII: In the cases classified as "good", with similar technique, the palmaris longus tendon gives better results as a graft than the sublimis of the same digit. This finding is most noticeable in this series in the high percentage of cases with flexion to less than one-half inch from the distal crease of the palm.

and as a buried suture in the palm. Here the end results were better, with flexion to the distal crease in the palm in 13 per cent. and only one failure. The percentage of "good" cases was slightly higher here than in any other group, although hardly enough to account for the marked improvement in results.

In the last series, not only was stainless-steel wire used throughout, but a deliberate excision of all remaining sheath tissue was done in the fingers, and in most instances the pulley in the middle segment was excised. Its action was restored by suturing the deep fascia with non-absorbable cotton sutures. In this series there were no failures and, in spite of the smaller percentage of "good" cases, the end results were better. Although none of the fingers had complete flexion to the distal crease in the palm, 87 per cent. flexed to within one and one-half inches. The curve can now be seen to rise more steeply and thus is approaching the ideal shown in Chart III.

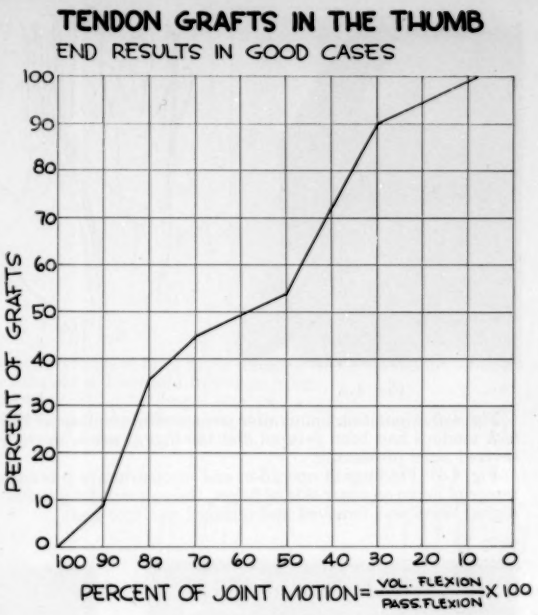

CHART VIII

Results of flexor-tendon grafting in the thumb, in a series of twenty-one cases treated by varying techniques. Better results were obtained by a long graft, extending from the terminal phalanx to the musculotendinous junction of the forearm, than by a proximal suture line placed in the thenar eminence.

Chart VI illustrates more clearly the effect of these changes in technique. A comparison is made of results in two series of cases in which the only variable factor was a change in technique, the 1938 series consisting entirely of silk sutures and the 1948 series entirely of wire with excision of the sheath. Each series comprised eight "good" cases; thus 12.5 per cent. on the vertical line represents one case. In the 1938 series, one case had flexion to the distal crease and all had flexion to within one and one-half inches. In 1948, one case had flexion to within one-quarter inch of the distal crease and all had flexion to within one inch.

INFLUENCE OF SOURCE OF GRAFT

Tendons to be used as grafts are better if of small diameter, so that they can be easily nourished by the surrounding tissues, which are often scarred from injury; the tendons should have a smooth, gliding surface. The palmaris longus tendon is ideal. However, it is absent in about 10 per cent. of patients and is often too short. The proximal portion of the sublimis tendon of the involved digit is next best. This, however, lacks the true paratenon layer which makes up the gliding surface of the palmaris longus, and is sometimes of greater diameter than is desired. Comparison of results (Chart VII) shows that a greater number of those fingers in which the palmaris was used can flex to touch the palm. Recent experience indicates that a deliberate block-removal of the true paratenon layer with the palmaris longus produces even better results, especially when much scarring is present. It has not been felt necessary to make a new sheath by the preliminary insertion of celloidin, plastic or stainless-steel ribbons, or tubes.

FIG. 4-A

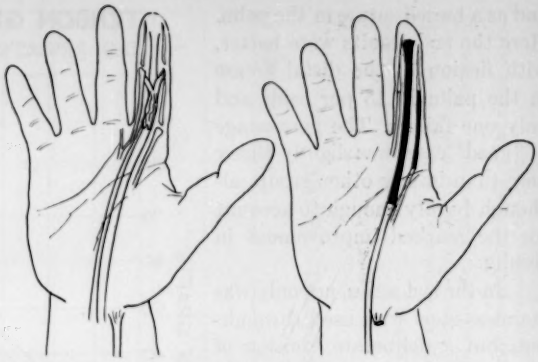

FIG. 4-B

Fig. 4-A: Condition found after unsuccessful primary and ill-advised secondary repair, at which time *both* tendons had been sutured and the digital nerve to the radial side of the index finger was again severed more proximally.

Fig. 4-B: Findings at operation and reconstructive procedure. After excision of all deep cicatrix and repair of nerve on ulnar side of finger, the palmaris longus was used as a free graft and a segment of the digital nerve was removed and replaced as a free graft.

FIG. 4-C

FIG. 4-D

Result of flexor-tendon graft, applied in 1938. Sensation returned in one year and stereognosis was present by the third year. (Reproduced, by permission, from *Annals of Western Medicine and Surgery*, 1: 148, 1947.)

COMPLICATIONS AND FAILURES

Of the 104 grafts in the fingers, there were ten instances in which the interphalangeal joints failed to flex to any appreciable degree following operation. These cases were classified as failures. Seven of these occurred in the series in which only silk sutures were used; in each instance there was a severe foreign-body reaction with drainage, requiring removal of the suture material. In three patients the complication occurred at the proximal suture line in the palm. One case involved all four fingers, accounting for four of the failures. In the second series, where silk sutures were used in the palm and pull-out wire sutures at the insertion, there were only two failures, both due to complications in the palm. One failure occurred in the third series and none in the last series.

Ten secondary operations were performed,—four in the first series, and three each in the second and third series. These operations were done after several months, in order to remove excess scar, free the tendons, or, in a few instances, to insert paratenon-like gliding tissues.

Minor flexion contracture, limiting extension of the digit at the middle joint, is not disabling. In twenty-seven instances (26 per cent.) there were flexion contractures of 5 degrees or more; in only five of these (4.8 per cent.) was the limitation more than 30 degrees.

FIG. 5-A

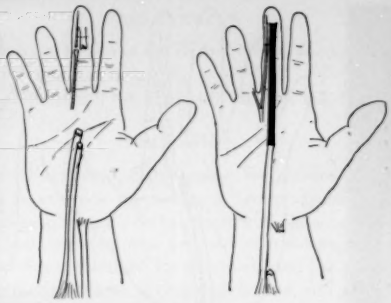

FIG. 5-B

FIG. 5-C

Fig. 5-A: Loss of flexion in long finger after severance of both flexor tendons. An unsuccessful primary repair, done through a lateral incision, fortunately did not add to the scarring.

Fig. 5-B: Findings and procedure at operation. Palmaris longus was used as graft.

Fig. 5-C: Photograph of hand shows resulting flexion. Extension was complete. (Reproduced, by permission, from *Annals of Western Medicine and Surgery*, 1: 148, 1947.)

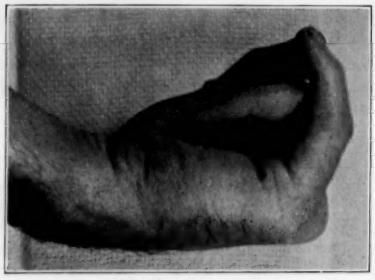

FIG. 6-A

FIG. 6-C

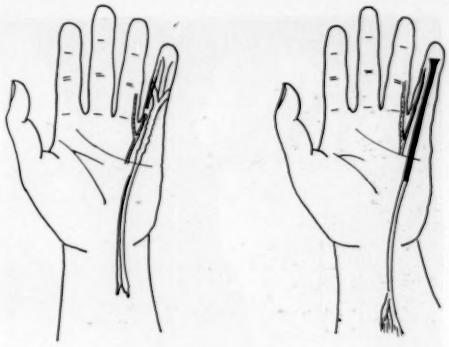

FIG. 6-B

Fig. 6-A: Both flexor tendons had been severed and sutured, resulting in loss of voluntary flexion, limited extension due to contracture, and even limited flexion of the ring finger.

Fig. 6-B: Findings and operative procedure. Sublimis graft was used.

Fig. 6-C: Amount of flexion possible after operation. The contracture limiting extension was not increased. (Reproduced, by permission, from *Annals of Western Medicine and Surgery*, 1: 149, 1947.)

TENDON GRAFTS IN THE THUMB

The end results are known in twenty-one of twenty-three cases in which flexor-tendon grafts were used in the thumb. Function was recorded by measuring in degrees the voluntary flexion of the interphalangeal joint. This figure was used as a numerator, the passive flexion of the joint being taken as a denominator. The fraction was then reduced to a percentage. The cases classified as "cicatrix", "joint", "trophic", and "multiple" are too few to be shown graphically, but the same general effect of preoperative condition on the end results was noted as in the series in the fingers. The results for the eleven cases in the "good" group are shown graphically in Chart VIII. As all injuries were in the thumb itself, the grafts were inserted into the distal phalanx and the proximal suture line was usually placed in the thenar eminence. In two cases a longer graft was used, and the proximal suture line was placed at the musculotendinous junction in the forearm. The

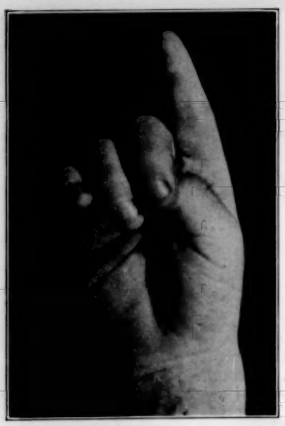

FIG. 7-A

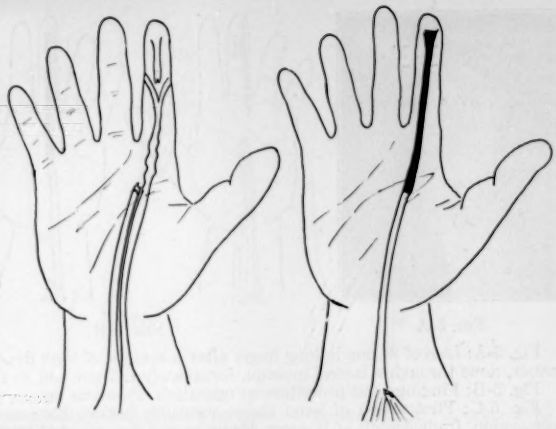

FIG. 7-B

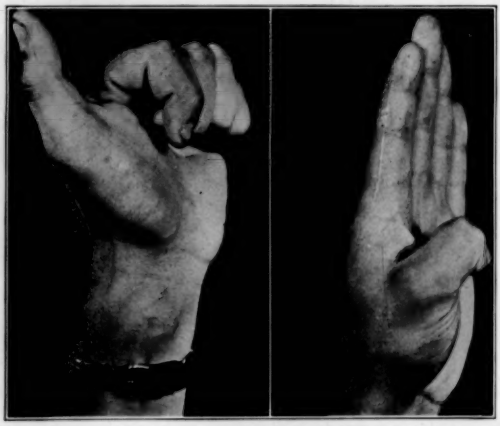

FIG. 7-C

Fig. 7-A: When both flexor tendons of the index finger had been severed and only the sublimis had been repaired, deep scar limited function.

Fig. 7-B: Reconstruction was done in 1939, when the patient was six years old, the sublimis tendon being used for a graft.

Fig. 7-C: Showing flexion and extension in 1947, at fourteen years of age. Tendon grafts live and grow in length in relation to the digits. (Reproduced, by permission, from *Annals of Western Medicine and Surgery*, 1: 150, 1947.)

results in these two cases were the best in the series, one attaining flexion of 95 per cent. of normal and the other 80 per cent. Utilization of a long graft to avoid a suture line in the palm should be done wherever possible [2].

CONCLUSIONS

A study of the end results in a series of flexor-tendon grafts in the fingers and thumb, inserted because of damage to the tendons in the "critical" zone, shows that the influencing factors, in order of importance, are cicatrix from injury or infection, stiffened joints, trophic changes, and damage to more than one digit. Improvement in results has followed the use of Bunnell-type of stainless-steel wire sutures in place of silk, combined with meticulous excision of scar and thickened sheath tissue. The use of the palmaris longus tendon as a graft has given better results than use of other tendons. In the thumb, a graft from the musculotendinous origin to the insertion is preferred. It has been shown that, under ideal conditions, the results of digital flexor-tendon grafts are as follows: In 25 per cent. of the cases flexion is complete, so that the pulp of the finger reaches the distal crease of the palm; in 50 per cent., the pulp reaches to within one-half inch of the distal crease of the palm.

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DISCUSSION

Dr. Sterling Bunnell, San Francisco, California: We all owe a debt of gratitude to Dr. Boyes for presenting accurate statistics to evaluate the results of tendon-grafting. By restricting the repairs to flexor tendons in the so-called "no-man's land", he has dealt with the most difficult part of tendon surgery. He has shown the superiority of stainless-steel wire over silk as a suture, and that a graft of the palmaris longus is better than one from the flexor sublimis. He also evaluated the results to be expected from flexor grafts in digits and showed the detracting effects, in order, of cicatrix, stiff joints, trophic changes, and multiple operations.

Statistics are a good guide in evaluating methods of procedure, but are of less value as the number of variables becomes overwhelming, which often occurs in hand reconstruction. Neither the preoperative condition nor the operative technique and procedures are standardized; the same is true of the results. Some additional but important intangible variants are: state of nutrition from lack of blood and nerve supply; difference in both the cicatricial index and in the stamina of individuals to exercise postoperatively; lessened strength and excursion of the muscle, depending upon the time interval since its tendon was severed; and magnitude of the operation, aside from the tendon repair.

Another equally important guide to evaluation of methods is personal experience, through daily correlation for years of changing procedures and results. Results vary according to the preoperative conditions that both Dr. Boyes and I have listed. My conclusions as to the merits of the various procedures are as follows:

Atraumatic technique is essential. For a suture, fine stainless-steel wire is preferable to silk. Usually removable wire is placed at insertions and buried flexible twisted wire is placed at the junction of graft and tendon. This allows early movement.

Grafts are needed in order to place junctures at strategic sites, as junctures are prone to adhere. A graft is so placed that its two junctures are never in a finger, in a carpel tunnel, or in the distal half of the palm, as they will adhere. One is made at the terminal phalanx, where it does not have to glide, and the other where it can glide in the base of the palm or above the carpal ligament. In the palm, the lumbricalis is wrapped about the juncture as its natural attachment. In the thumb, a graft from the distal phalanx reaches to above the carpal ligament, thus avoiding a juncture with the thumb or thenar eminence. A graft of gliding assembly —namely, tendon plus paratenon, as from the palmaris longus or long extensors of the toes—yields more motion than a graft of a tendon alone, such as the sublimis. A narrow tendon is preferable to a thick one, as the smaller surface furnishes less area for adhesions.

In after-treatment, more freedom of motion is permitted than formerly, although this is still quite limited. Weak, guarded movements, free from strain, are commenced on the first postoperative day and are continued.

The evaluation of end results has been made by Dr. Boyes.

Dr. Walter C. Graham, Santa Barbara, California: Dr. Boyes' presentation is the first well followed and completed study of cases of tendon-grafting that has been reported, to my knowledge. His method of measuring flexor-tendon function is a definite contribution. This method is much simpler than attempting to measure and record the flexion of each individual joint, and also has the advantage of giving an actual picture of the situation which one can compare with that in his own hand.

The recent great improvement in results is definitely due to changes in technique, which were developed over a period of years. This technique includes not just the operation, but also the follow-up care, which is extremely important. The use of wire in preference to silk is an additional factor in the progressive improvement. One might consider that the more meticulous selection of cases is also a factor. The fixation of the distal end of the graft to the stump of the profundus tendon or to the periosteum at the insertion of the tendon plays an important part in producing flexion of the distal interphalangeal joint.

Suturing the nerves at the time of tendon-grafting is usually inadvisable, as the patient will tend to substitute the adjacent finger for the one which has been grafted. This is particularly true when the injury involves the index finger. Invariably, this finger will be held in extension to prevent it from getting in the way as the thumb contacts the middle finger, which has sensation. I find it advisable to give a few degrees of fixed flexion at the proximal interphalangeal joint, with the stump of the sublimis tendon acting as a check-rein. This requires fixing the sublimis to the periosteum of the proximal phalanx with a fine suture. The fact that flexion is already initiated in this joint prevents the snapping which occasionally occurs in so-called "loose-jointed" individuals.

Time prevented Dr. Boyes from covering postoperative care, which is the most important factor in mobilizing the graft. Occasionally, adhesions will form, which can be broken up by blocking the medial or

(*Continued on page 531*)

CONGENITAL METATARSUS VARUS

Report of 300 Cases *

BY J. HIRAM KITE, M.D., ATLANTA, GEORGIA

From the Scottish Rite Hospital for Crippled Children, Decatur

Congenital metatarsus varus may be thought of as being a "third of a club foot". It is a condition which has been occurring with increasing frequency during the last few years. The adduction and inversion deformity of the fore part of the foot, which is frequently overlooked at birth, becomes more marked during the first few months of life. Little tendency toward spontaneous recovery has been observed.

Thirty or forty years ago, a series of articles on this subject appeared in the European literature; they were reviewed in 1933 by Peabody and Muro. The objective of the earlier workers apparently was to separate, from the common deformity of club-foot, another entity which consisted of adduction deformity of the fore part of the foot and valgus deformity of the heel. They debated whether the new deformity was simply adduction of the fore part of the foot or whether the foot was also inverted. Some preferred the term "metatarsus adductus"; others preferred "metatarsus varus".

The first case was described by Henke in 1863. Helbing reported four cases among 5,000 children admitted to Hoffa's clinic. Ettorre, in 1921, found seven cases among 480 congenital foot deformities at the Orthopaedic Clinic of Milan. In 1933, Peabody and Muro reported fourteen cases.

Cases of congenital metatarsus varus may be divided into two groups. The first group is small; the condition is severe and shows no tendency to increase in frequency. In the records of the Scottish Rite Hospital for Crippled Children, only nine such cases have been found, similar to those described in the literature. These nine severe cases showed a strong hereditary tendency and had other congenital deformities. All the patients had fixed valgus of the heel. The deformity was resistant to treatment, and could not be corrected by months of casts and wedgings; operative treatment was required in most cases. All of these patients had some recurrence of the deformity after correction, and in several a second operation was needed.

In the second group, the condition is not hereditary, there are few associated congenital deformities, and there is no fixed valgus of the heel. The deformity yields readily to treatment and shows little tendency to recur. In this group, which is increasing, are included the 300 cases reported in this paper.

Since the cases have been separated, a different terminology may be applied to each group. The early European writers preferred the term "metatarsus adductus", which is applicable to the smaller group of cases. The term "metatarsus varus" more accurately describes the large group of patients being seen today. When the infant is placed on his feet, the term "adductus" describes the appearance of the fore part of the foot; but when no weight is borne, the fore part of the foot is inverted and the term "varus" more accurately describes the condition. Since the term "metatarsus varus" conveys no meaning to the parents, the condition is explained to them as being a "third of a club foot".

CLINICAL FINDINGS

The most characteristic finding in these cases is the adduction and inversion of the fore part of the foot (Figs. 1-A, 1-B, and 1-C). The arch is higher than normal. The more

* Read at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 21, 1949.

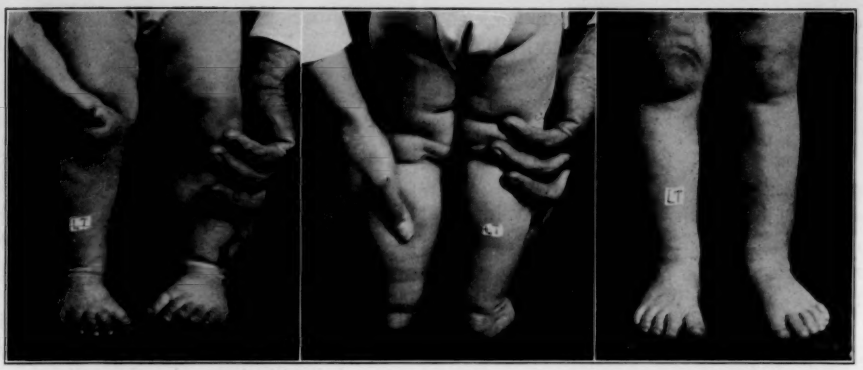

FIG. 1-A FIG. 1-B FIG. 1-C

A typical case of metatarsus varus of about average severity. There is adduction of the fore part of the foot, a higher arch than normal, and a prominence on the lateral border of the foot. In metatarsus varus the heels may be straight under the mid-line of the tibia, or in a slightly varus or valgus position. Fig. 1-C shows the result after correction by casts and wedgings.

advanced cases have a prominence on the lateral border of the foot. The heel is so nearly in the mid-line that it is almost impossible to tell whether it is in varus or valgus position, but certainly it is not in fixed valgus.

The one finding which will separate these patients from those with congenital club-

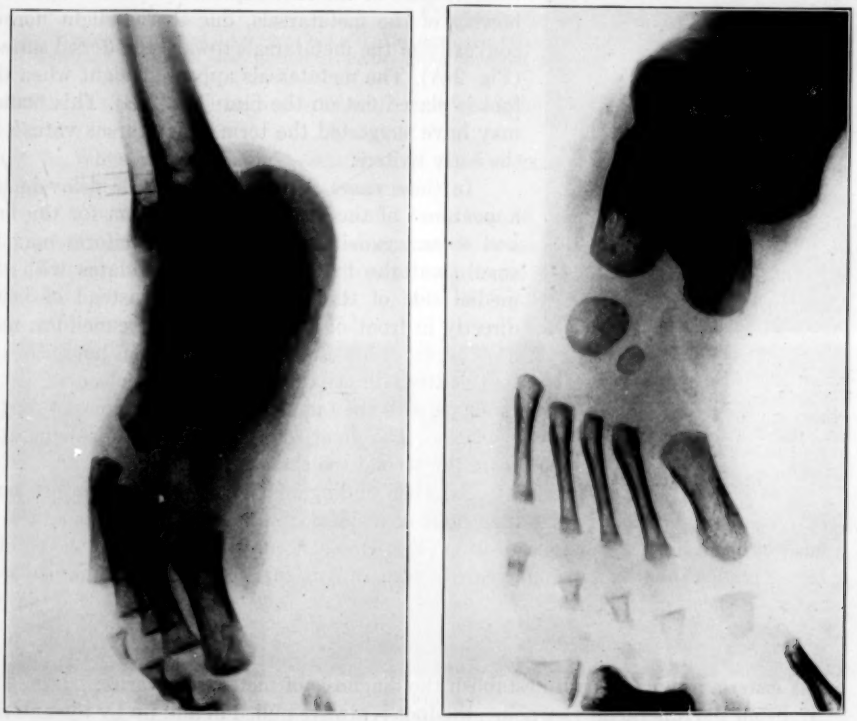

FIG. 2-A FIG. 2-B

Fig. 2-A: When roentgenograms are taken with the foot in supination, the metatarsals appear curved, due to the normal convexity of the metatarsals toward the dorsal surface.
Fig. 2-B: When the foot is placed flat on the film, the shafts of the metatarsals are straight.

foot is that equinus deformity is never seen in this group. Since there is no equinus and no constant clinical deformity of the heel, the adduction and inversion of the fore part of the foot remains as the only one of the three deformities comprising club-foot.

PATHOLOGICAL ANATOMY

In metatarsus varus, there is congenital muscle imbalance. Some of the early writers questioned whether metatarsus varus was an acquired or a congenital deformity. Most congenital deformities are fully developed at birth. In only 94 of the 300 cases reported here was the deformity recognized at birth. The average age at which it was recognized in other cases was 2.8 months. Since the muscle imbalance is congenital, the deformity increases with the lapse of time, as with deformities following poliomyelitis.

At operation on an eight-year-old boy, Peabody and Muro found that the anterior tibial tendon, instead of being inserted into the first cuneiform and the base of the first metatarsal, had no tarsal attachment, but continued distally in its sheath until opposite the shaft of the first metatarsal, meeting it at a wide angle and passing beneath it to the plantar fascia or transverse metacarpal ligament.

ROENTGENOGRAPHIC STUDY

Roentgenograms show varying degrees of adduction of the fore part of the foot. There is usually valgus deformity of the heel, as evidenced by a wide separation of the anterior end of the calcaneus and the head of the talus. When anteroposterior roentgenograms are made with the fore part of the foot supinated, there is apparent bowing of the metatarsals, due to the slight normal convexity of the metatarsals toward the dorsal surface (Fig. 2-A). The metatarsals appear straight when the foot is placed flat on the film (Fig. 2-B). This finding may have suggested the term "metatarsus varus" to the early writers.

FIG. 3

There is a wide separation of the great toe from the second toe in many of these cases. The first metatarsal articulates with the first cuneiform on the medial side, instead of directly in front of it.

In these cases there is considerable delay in the appearance of the centers of ossification for the first and second cuneiforms. The first cuneiform may be small, and the first metatarsal articulates with the medial side of the first cuneiform instead of being directly in front of it. The small first cuneiform may account for the concavity of the medial border of the foot at this site. The remaining four metatarsals form an angle with the tarsus of about 45 degrees of medial deviation. The great toe is frequently more separated from the second toe than normal (Fig. 3).

Another finding of significance, which has only recently been appreciated, is that the center of ossification for the navicular is lateral to the head of the talus in a flat-foot position (Fig. 4). This center appears when the child is between eighteen months and four years of age. In congenital club-foot the navicular is medial to the head of the talus.

DIAGNOSIS

Six criteria are necessary to establish the diagnosis of metatarsus varus:

1. From the functional viewpoint, the foot is always pulled in and up by the anterior tibial muscle.

Structurally, there is (2) adduction and inversion of the fore part of the foot, (3) a higher longitudinal arch than normal, and (4) a prominence on the lateral and dorsal

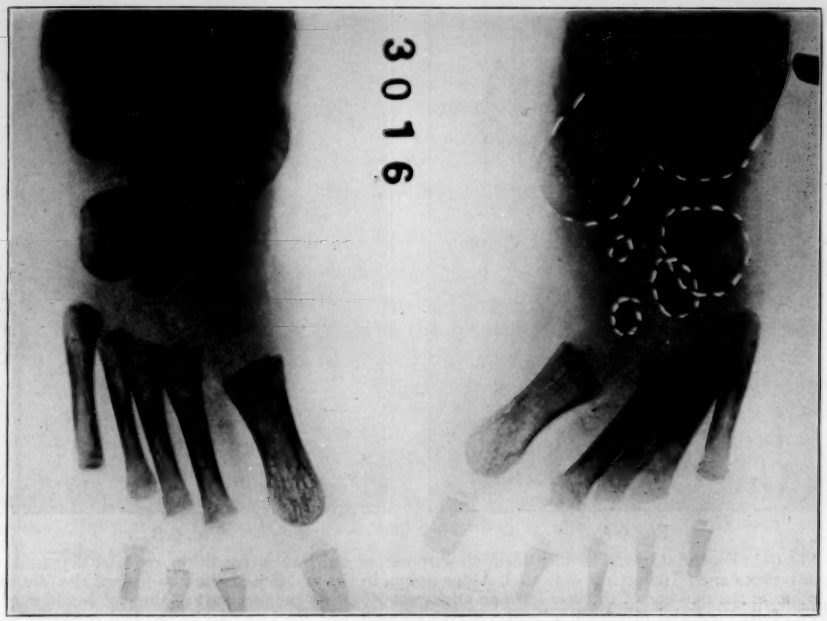

FIG. 4

Roentgenogram of a two-year-old girl. The navicular is lateral to the head of the talus in a flat-foot position, rather than medial to the head in a club-foot position.

surface of the foot in the region of the cuboid and the base of the fourth and fifth metatarsals.

5. When the heel is held securely and the fore part of the foot is abducted, there is more resistance to abduction than normal.

6. The fore part of the foot cannot be abducted past the mid-line (Fig. 5-A). This point is missed if the foot is abducted against the resistance of the leg (Figs. 5-B and 5-C). In addition, the heel may be in a varus or valgus position. There is no limitation of dorsiflexion.

FIG. 5-A FIG. 5-B FIG. 5-C

Fig. 5-A: The fore part of the foot is not so flexible in metatarsus varus as it is in a normal foot, and cannot be abducted past the mid-line.

Fig. 5-B: This point is missed if the fore part of the foot is abducted against the resistance of the leg.

Fig. 5-C: To appreciate the amount of stiffness present, the heel must be held securely with one hand and the fore part of the foot abducted with the other.

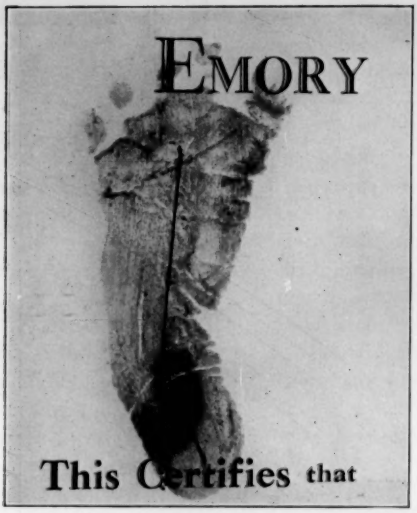

FIG. 6-A

FIG. 6-B

Fig. 6-A: Footprint, made for identification purposes, of a girl whose condition was later diagnosed as metatarsus varus. The arch is indicated. A line drawn in the mid-line of the fore part of the foot and another in the mid-line of the heel form an angle, showing that the fore part of the foot is adducted.

Fig. 6-B: Footprint of patient's brother shows no arch, and the fore part of the foot is in line with the posterior portion. This boy has normal feet.

Footprints made for identification purposes at birth may be an aid in the early diagnosis of this deformity (Figs. 6-A and 6-B). The normal foot usually gives an imprint with no arch; in metatarsus varus the foot has an arch. If a line is drawn through the middle of the heel and the middle of the fore part of the foot, the adduction of the fore part is easily demonstrated.

DIFFERENTIAL DIAGNOSIS

Congenital metatarsus varus as it occurs in infants must be differentiated from several other "metatarsus varus-like" deformities.

When the child is "pigeon-toed", one must also think of *medial torsion of the leg*. The leg presents a curve with lateral convexity, and medial torsion which turns the feet inward. The feet are normal, and there is no angulation of the fore part of the foot.

Recurrent club-foot may give findings identical with metatarsus varus, but the history of the original deformity, the treatment used, and the presence of equinus establish the diagnosis.

In *spina bifida* the feet may present a metatarsus varus type of deformity; but since the muscle imbalance and the response to treatment are different, these cases should be studied separately.

Occasionally the feet in *arthrogryposis multiplex congenita* may be similar in appearance, but the stiffness in the feet and in other joints of the body will establish the diagnosis.

Friedreich's ataxia may produce a somewhat similar appearance of the feet, but the other signs of this condition, together with the history of other cases in the same family, should eliminate confusion.

Finally, the small group of "metatarsus adductus" cases, mentioned earlier, should be separated from this larger group.

ETIOLOGY

The etiology is unknown. The condition is not hereditary. The mother of only one of

the 300 patients in this series had a condition which might be diagnosed as metatarsus varus.

Metatarsus varus is occurring with increasing frequency, in contrast to relatively slight fluctuation in the frequency of occurrence of other congenital deformities. During the fourteen years from 1924 to 1938, fourteen cases were seen, an average of one a year. During the next five years the average was four a year; in 1943, nineteen cases were seen. Each year the number of new cases has gradually increased, eighty-one being seen in 1948.

STUDY OF CASES

Three hundred cases of congenital metatarsus varus have been reviewed. There were 165 males (55 per cent.) and 135 females (45 per cent.). Fifty-one per cent. of the cases were bilateral. Of the unilateral cases, the deformity was on the right in 23 per cent. and on the left in 26 per cent. An associated club-foot deformity was present in thirteen cases. In twelve cases there was calcaneovalgus deformity in the other foot, severe enough so that casts were needed for its correction.

TREATMENT

Since the variation in severity of the deformity is greater in metatarsus varus than in club-foot, the method of treatment will vary according to the severity.

Seventy-seven cases, or approximately one-fourth of this series, were so mild that casts were not needed for correction. No treatment was recommended for the mildest cases, but in most instances treatment consisted in having the mother stretch the feet in abduction and in having the child wear "swung-out" shoes.

To accomplish anything by "stretching", the mother has to be carefully taught how to hold the fore part of the foot in one hand and the heel in the other, how to bring the fore part out in abduction, and how to make pressure inward on the prominence on the lateral border of the foot. She should be told that the procedure is not massage and not a wiggling of the foot, but that the foot should be held steadily and firmly, as a cast would hold it. It is suggested that she hold the foot this way for half a minute and release it, then repeat for another half minute, continuing until she has spent five minutes on the foot. This should be done every night and morning, and for a few times whenever she handles the baby. If there is no improvement in a month, casts should be applied. The casts assure correction and relieve the mother of a tedious task.

The child who is being treated without casts may wear "swung-out" shoes, if he is old enough for hard-soled shoes. The pronator shoe, advocated by some for the after-treatment of club-foot, should not be used. These shoes have a lift under the lateral border of the heel, and increase the valgus deformity of the heel. If there is any valgus deformity of the heel, it is better to have a shoemaker alter a pair of stout normal shoes by swinging the fore part out and keeping the heel level, or by raising the heel one-eighth of an inch on the medial side.

The treatment by casts and wedgings is similar to that used in club-foot for the correction of the adduction of the fore part of the foot, but care must be taken not to turn the heel out into a valgus position. A plaster shoe is first applied to the foot; one roll of plaster is used on the fore part of the foot and one on the posterior portion, so as to make a plaster shoe like an oxford. While the plaster is setting, the fore part of the foot is held in abduction. The foot is placed on a flat surface to keep the sole in a normal weight-bearing position. Pressure is exerted on the prominence on the lateral aspect of the foot until the plaster has hardened. If there is any valgus deformity of the heel, this is corrected by turning the foot and the plaster shoe into an inverted position. The foot is held at a right angle with the leg, since there is no equinus deformity to be corrected. The plaster is continued up over the knee to the mid-thigh, with the knee flexed nearly to a right angle. The casts are changed weekly until the baby is three months old, so that they do not become tight

during the rapid growth of infancy. After the patient is three months old, the fore part of the foot may be wedged in abduction, as in the treatment of club-foot. The adduction of the fore part of the foot in the average case is corrected in about four weeks, and the foot is then held in a slightly overcorrected position for three or four weeks longer. Normal shoes are worn. The parents need not stretch the foot unless there is a recurrence.

Constant care must be exercised in applying these casts not to follow the club-foot routine and turn the heel in a valgus position. Also, the feet must not be held in casts for too long a time in the overcorrected position, or flat-foot will result. It is less embarrassing to the surgeon to correct a recurrent metatarsus varus deformity which nature has produced than it is to correct a bad flat-foot deformity for which he has been responsible.

SUMMARY

Congenital metatarsus varus may be thought of as being "a third of a club foot". The condition has been occurring with increasing frequency during the last few years. The adduction and inversion of the fore part of the foot, which are frequently overlooked at birth, become more marked during the first few months of life, due to the strong pull of the anterior tibial muscle.

Cases of metatarsus varus have been divided into two groups. The smaller group, consisting of more severe cases with a strong hereditary tendency and associated congenital deformities, are most resistant to treatment. The patients in the larger group show no hereditary tendency or allied deformities, other than those associated with the feet, and have no fixed deformity of the heel. They respond readily to treatment and show little tendency to recurrence. This group is increasing.

Six criteria are necessary to make the diagnosis. From the functional viewpoint, the foot is always pulled in and up; and from the structural viewpoint, there is adduction and inversion of the fore part of the foot, a higher arch than normal, a prominence on the lateral border of the foot, and greater rigidity of the foot, which cannot be abducted past the midline.

Three hundred cases have been studied. The treatment has been by casts and wedgings, similar to those used for the correction of the adduction deformity in club-foot, care being taken not to produce a flat-foot deformity.

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CONGENITAL DISLOCATION OF THE HIP

Development of the Joint after Closed Reduction

BY ERIK SEVERIN, M.D., GOTHENBURG, SWEDEN

From *Ortopediska Kliniken, Vanföreanstalten, Göteborg*

The development of the arthrographic method has made it possible to study features of the infant hip joint formerly inaccessible to observation. An ordinary roentgen picture shows only the shape and position of the ossified portions of the joint. During early childhood, however, large areas of the femoral head and acetabulum are still cartilaginous, and only by injecting contrast medium into the joint space can the articulating surfaces of the joint be visualized.

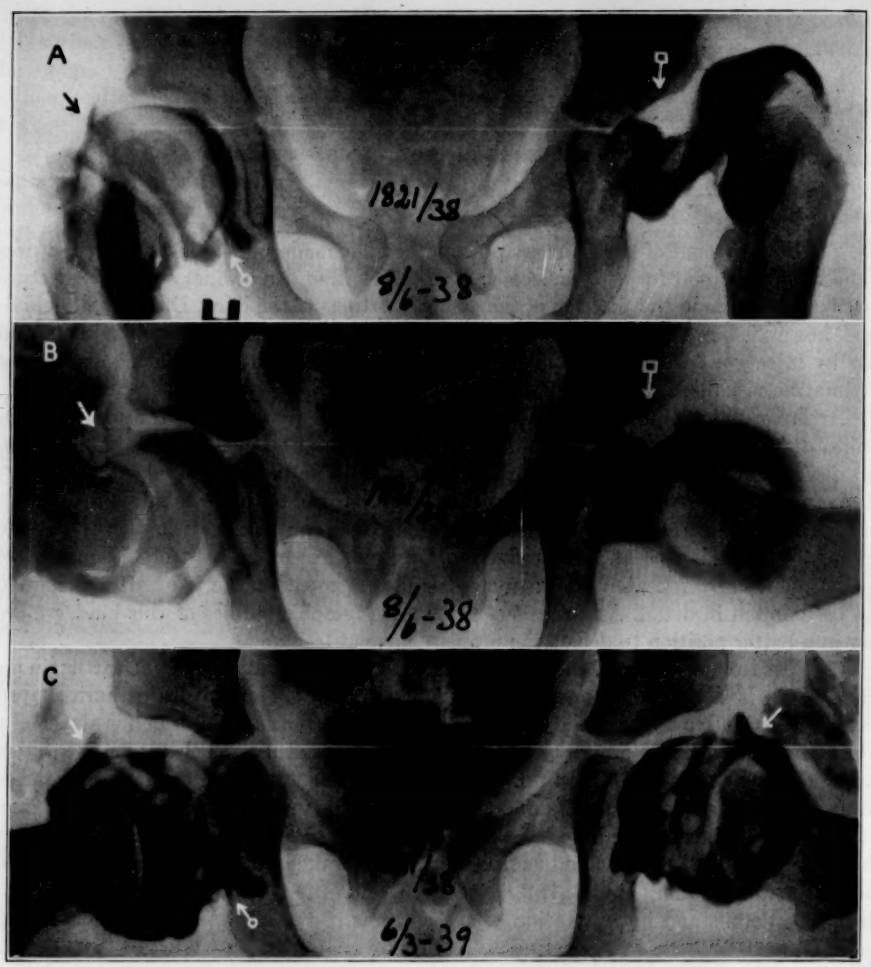
Arthrographic examination has proved to be particularly useful for the study of congenital dislocation of the hip. It permits strict differentiation of dysplasia, subluxation, and dislocation. Study can be made of the shape and size of the femoral head, the cartilaginous roof of the acetabulum, the adaptation of the head to the acetabulum in different positions, and the width of the capsular isthmus. One can also see whether or not the ligamentum teres is present. After reduction, the kind or degree of any soft-tissue barriers can be judged. By repeated arthrograms, the development of the joint after reduction can be followed in detail. As a result of serial arthrographic studies of this kind, we are now in a better position to decide the proper course of treatment.

The position of the tip of the limbus, and thus of the lateral edge of the cartilaginous acetabulum, is determined on the arthrogram with the aid of the little thorn-shaped accumulation of dye between the edge of the limbus and the capsule, which is attached a few millimeters higher. Normally, the tip of the limbus is visualized close to a line drawn through the Y cartilages,—the "Y line" (Fig. 1,*A*). In subluxation the femoral head is displaced proximally and laterally and the tip of the limbus no longer reaches the Y line, although the limbus still embraces the head to some extent (Fig. 5,*A*). After still greater displacement of the head, the limbus releases its grip on the head and slides down between the head and the ilium (Figs. 1,*A*, 2,*A*, 3,*A*, 4,*A*, and 5,*A*). The dislocation is then complete. The details and interpretation of arthrograms of the hip have been discussed by Faber, Leveuf, Wiberg, and Severin.

The series presented here consists of 115 cases of congenital dislocation of the hip, thirty-eight of which were bilateral and thirty-nine unilateral, all treated by closed reduction during the years from 1937 to 1940*. Arthrograms were taken at the time of reduction in all cases, both in order to verify the diagnosis and to study the primary effect of the reduction. In one-third of the 115 cases, one or several arthrograms were taken during the course of treatment. Most of the patients were treated before the age of three, and all before the age of five. In two cases, the treatment was begun before the child was a year old. In seventy-two cases, it is now possible to judge the clinical and roentgenographic results, five years or more after the reduction.

The treatment was carried out as follows: Careful reduction was done over the posterior edge of the acetabulum. Plaster was applied to the lower extremity and trunk on each side, whether the dislocation was bilateral or unilateral, with the hips flexed 90 degrees and abducted from 60 to 70 degrees. The knee joints were left free to allow rotatory movement in the hips. The child was encouraged to move his lower extremities during the entire time he was in the cast. After three or four months he was changed to a varnished wooden cast, where by supple saddle girths, his limbs were kept in the same

*Three cases, seen during the same period, have been excluded from the series because all attempts at reduction were unsuccessful.



R FIG. 1* L

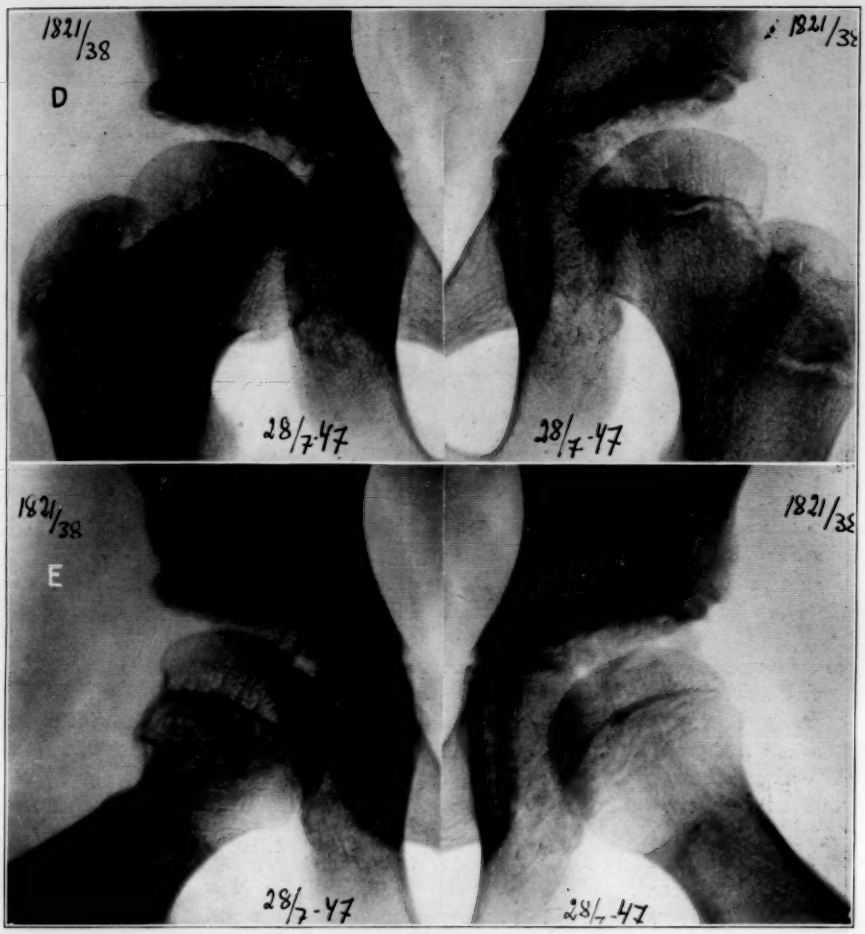
A and *B*: No. 1821/38, June 8, 1938. A girl, aged one year and ten months, had a normal right hip. The left hip was completely dislocated, showing a small deformed femoral head, a long and constricted capsular tube, and a broad ligamentum teres. After closed reduction the limbus was interposed and there was a deep pool of dye in the acetabular floor.

C: Arthrograms taken on March 6, 1939, almost nine months after the reduction, show that the left femoral head had acquired the same spherical shape and size as the right femoral head, and reached to the bottom of the acetabulum. The limbus was well developed and its tip reached to the Y line.

position as when in the plaster. Careful creeping and walking exercises were then begun. Six or eight months after the beginning of treatment the patient was allowed to move about freely, except that the abduction treatment was continued at night and for at least two hours during the day for two or more years after reduction.

Completely normal conditions in the hip, the limbus fitting around the femoral head with its tip reaching down to the Y line, are never observed immediately after reduction in cases of complete dislocation. In half of these cases the limbus remained inserted between the femoral head and the ilium (Figs. 1,*B* and 5,*B*). In the other half, the head

* → = Tip of the limbus.
⊐→ = Limbus bent back between the femoral head and the ilium.
○→ = Transverse ligament.

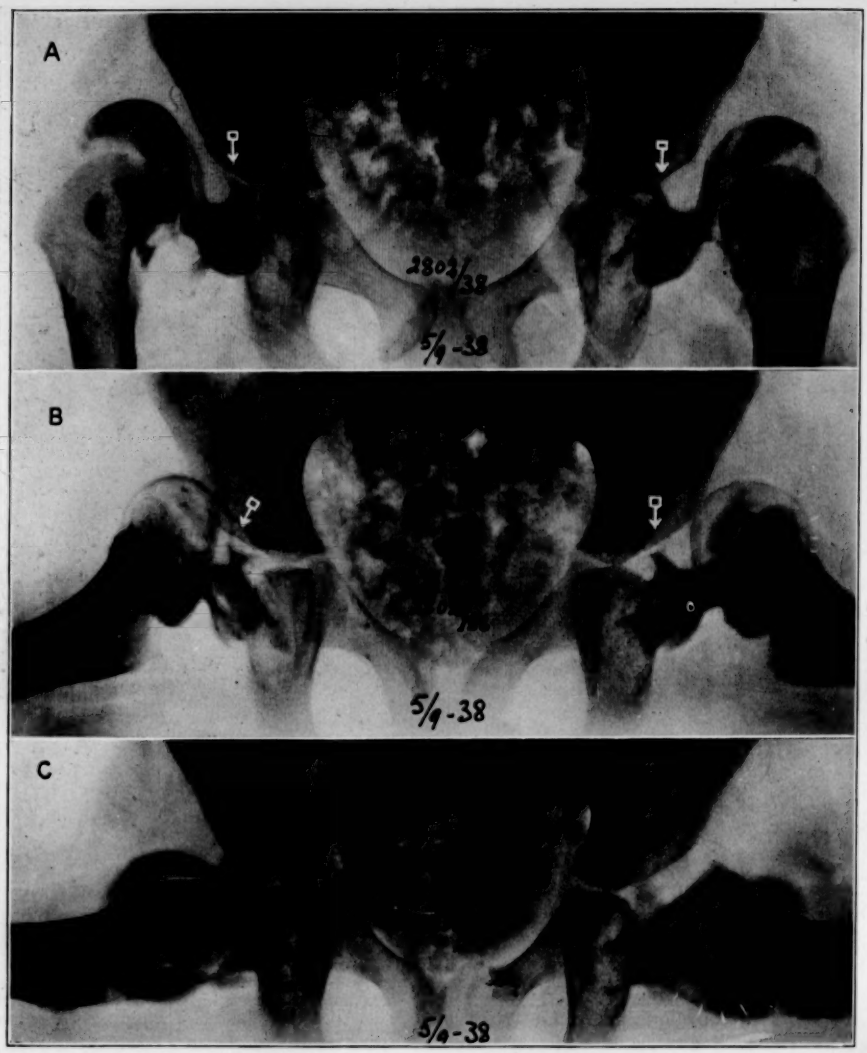


R FIG. 1 (*continued*) L

D and *E*: July 28, 1947, nine years and one month after closed reduction. The right hip had a deformity between the femoral head and neck, but was otherwise normal. The left hip showed a well rounded femoral head with a low epiphyseal nucleus and a well developed acetabulum. The hip was classed in Group I.

squeezed in under the limbus. However, the limbus did not immediately assume its natural position around the head in these cases, probably being prevented by adhesions to the ilium and by changes in its own structure.

The interposition of soft tissues in the form of an inserted limbus, a long ligamentum teres, an hourglass constriction of the joint capsule, or secondarily developed soft tissue in the floor of the acetabulum, may prevent the head from going into the socket. A barrier of this kind is generally visualized in the arthrogram by a pool of contrast medium in the floor of the acetabulum. Sometimes the arthrogram can indicate what it is that hinders the reduction. Usually the limbus is seen to be interposed. If a big ligamentum teres was observed before reduction, and after reduction there is a patchy contrast pool in the acetabular floor, the chances are that the patchiness is due to folds of this ligament. Occasionally it can be seen that the head is captured in a funnel, as it were, by the constricted capsule, the part of the capsular tube lying medial to the isthmus filling out the

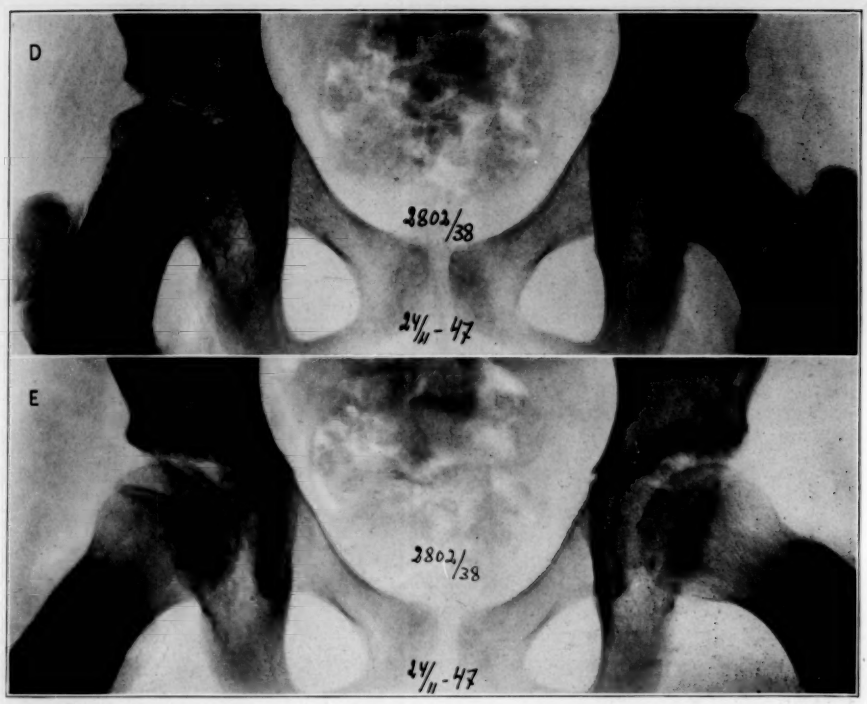


R FIG. 2 L

A, *B*, and *C*: No. 2802/38, September 5, 1938. A girl, aged three, had complete bilateral dislocation with an inserted limbus and a small, unevenly rounded femoral head on each side. After closed reduction soft tissue, probably the limbus, was interposed on each side. The pool of dye on the right side was 5 millimeters deep; on the left side, 8 millimeters deep. Treatment of the right hip was uneventful. The left hip became redislocated twice during the first few weeks after reduction. Two months after the first reduction, therefore, arthrotomy and a shelf operation were performed. No hindrances to reduction were found at that time, the soft-tissue barrier having apparently receded during the period of closed treatment. The constructed acetabular roof was soon absorbed and, therefore, could hardly have had any effect on the further development of the joint.

acetabulum like a cushion. The interposition of soft tissues with a contrast pool in the arthrogram was observed in two-thirds of the cases.

The absence of a contrast pool, however, does not guarantee that no soft tissue is interposed. The head may be pressed so tightly against a compact cushion of soft tissue that there are no spaces between for the dye to enter. In cases of this kind there may be a remarkably long distance between the pelvis and the epiphysis of the femoral head,



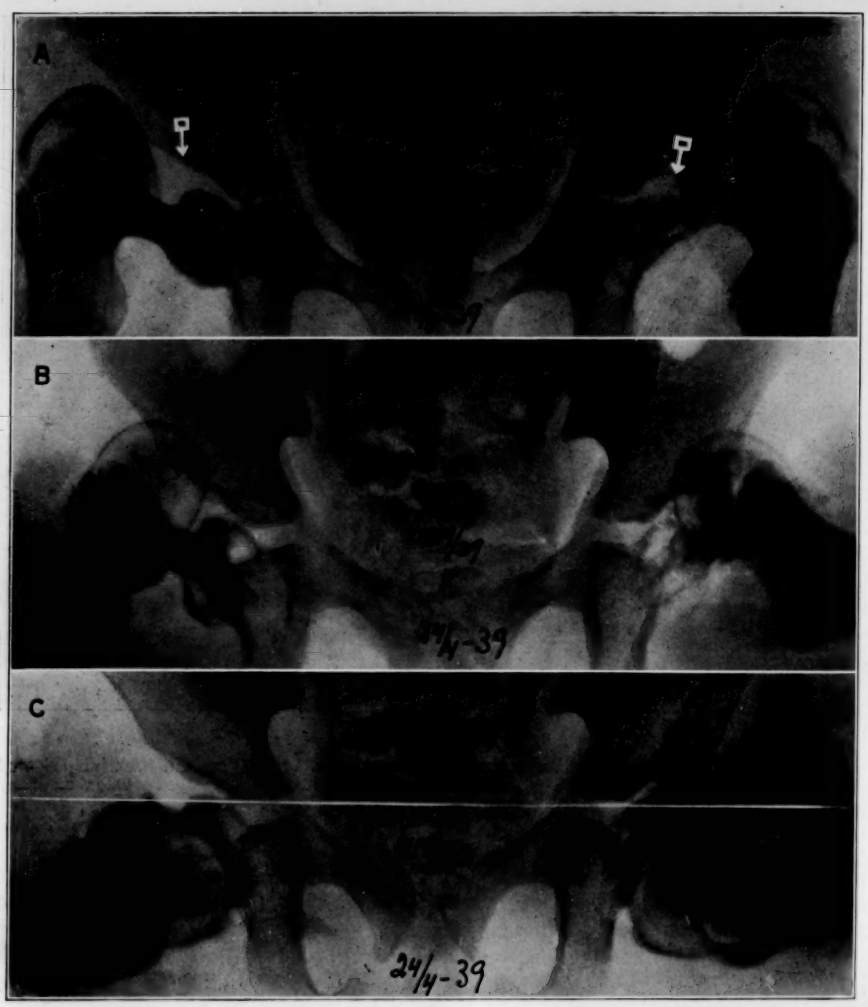
R FIG. 2 (*continued*) L

D and *E*: By November 24, 1947, nine years and two months after closed reduction, each hip showed a spherical femoral head with a fairly low epiphyseal nucleus and a well developed acetabulum. They were classed in Group I.

with decrease in this distance during the course of the treatment. It is not possible to rely on measurements of this distance, however. The situation is better clarified by a second arthrogram, taken a few weeks after reduction.

Thus soft tissue intervened between the femoral head and the pelvis after reduction in the two-thirds of the cases with a contrast pool, and in some of the cases without a contrast pool. It is not possible to state the exact number of cases of the latter type. However, it may be considered as established that soft tissue is interposed between the femoral head and the acetabulum in the great majority of cases, immediately after reduction of congenital dislocation of the hip.

Follow-up arthrograms during continued closed treatment have shown that the barrier is gradually overcome as long as the head is held in the reduction position opposite the acetabulum (Figs. 4,*D* and 5,*C*). This happened in all of our cases in which soft-tissue interposition was observed immediately after the reduction. Arthrograms taken at various intervals after reduction show that the head squeezes into the socket after one or two weeks; after a few months the limbus assumes a normal position over the head. The hourglass constriction of the capsule opens because of the pressure of the femoral head, and other obstructing soft tissues recede or become atrophied. A favorable development of this kind was also observed in cases of redislocation and renewed reduction, provided the second reduction was done within a few weeks of the beginning of treatment. One can also see how the growth of the femoral head is stimulated by the reduction (Figs. 1,*C* and 4,*D*). A femoral head which was small and deformed at the time of reduction may, six months to a year later, have acquired the same size and spherical outline as the



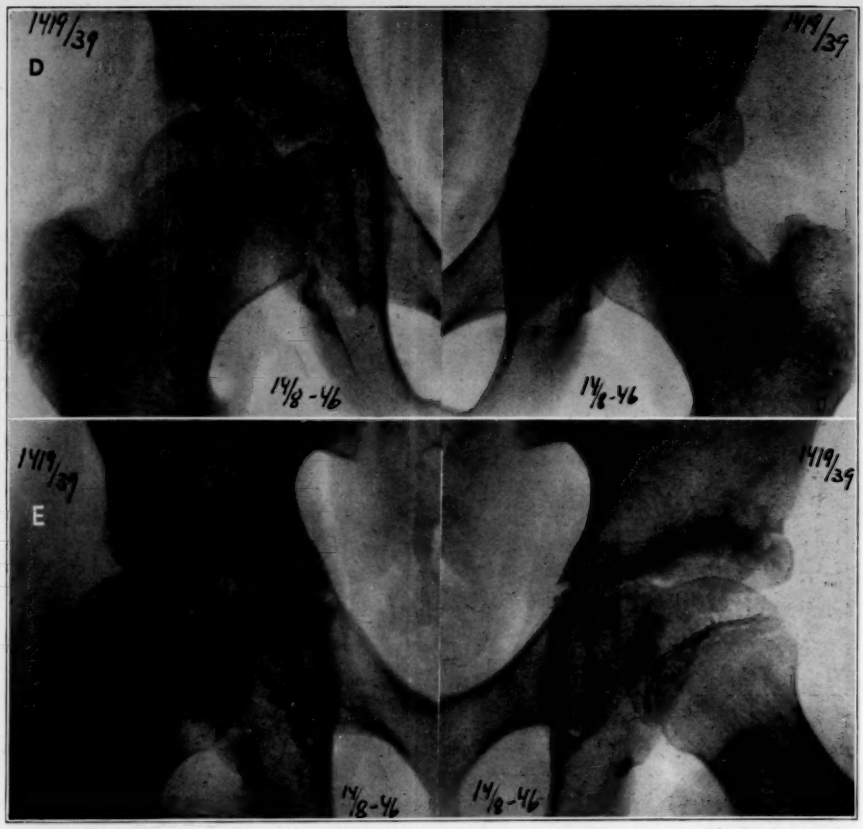
R FIG. 3 L

A, *B*, and *C*: No. 1419/39, April 24, 1939. A girl, aged two years and two months, had complete bilateral dislocation, with hourglass constriction of the capsule and an inserted limbus. After closed reduction, deep pools of contrast matter were seen on both sides. The limbus was still inserted on the right side, but was not in contact with the femoral head. It was not possible to ascertain exactly the position of the limbus on the left side after reduction.

head in a normal hip. It is often observed that this growth leads to abnormal enlargement of the head. When there are changes of the coxa plana type with fragmentation of the epiphyseal nucleus, the femoral head grows, but acquires an ellipsoid rather than a spherical shape.

Thus arthrograms have shown that the soft-tissue obstructions to complete reduction can generally be overcome by closed treatment.

A clinical and roentgenographic check-up was made five years or more after the reduction in seventy-two cases (Table I). The anatomical results were divided into six groups, in accordance with the criteria previously described[5]. Most of the subluxations, or twenty-one of the twenty-seven, were of only slight degree. The interposition of soft tissue did not affect the outcome. Relatively speaking, good results were obtained just



R FIG. 3 (*continued*) L

D and *E*: August 14, 1946, seven years and three months after closed reduction. Each side showed an evenly rounded femoral head, correctly situated in a well developed acetabulum. Both hips were classed in Group I.

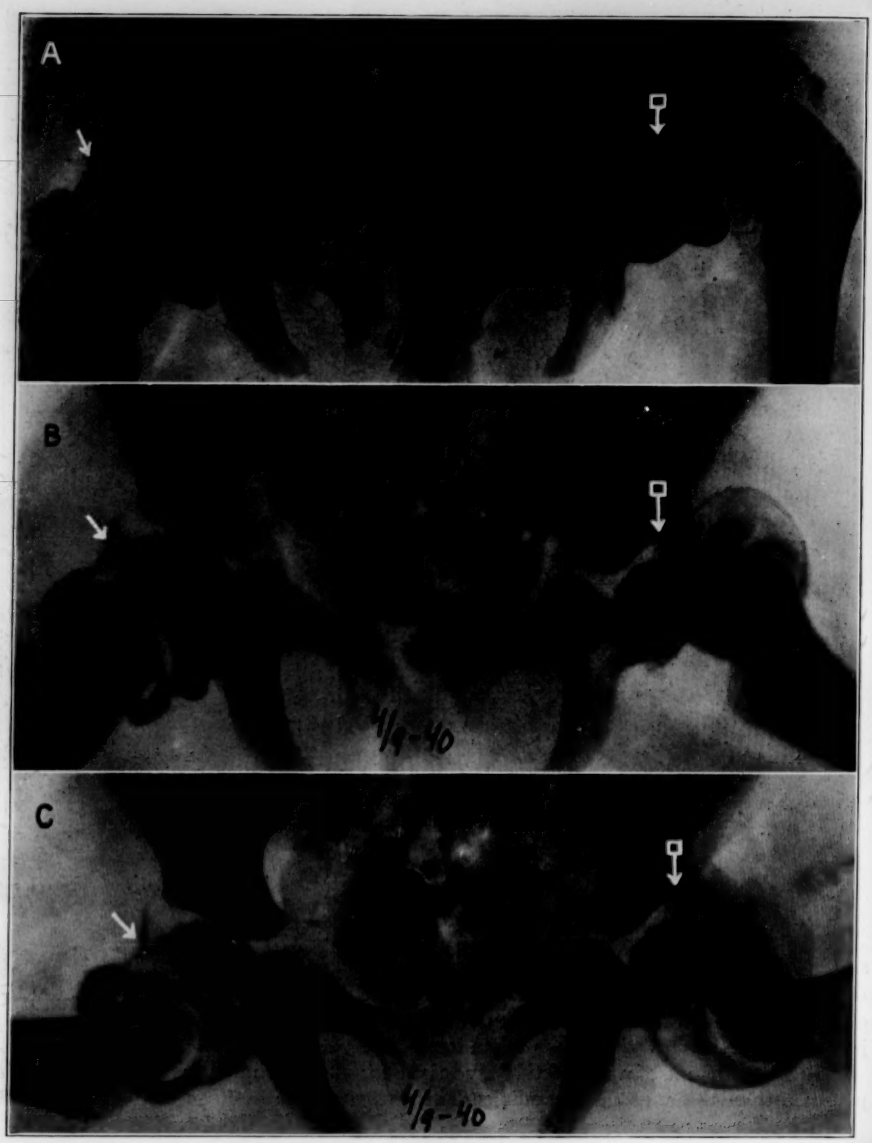
as often in the cases of unequivocal interposition as in the other cases (Figs. 1 to 5). On the other hand, some cases which looked favorable in the arthrograms taken at the time of reduction had a less favorable course later. In other words, the outcome cannot be judged entirely from arthrograms taken immediately after reduction.

From the point of view of this investigation, the functional results are of less importance than the anatomical findings. The patients were between the ages of six and

TABLE I

CLASSIFICATION OF RESULTS FIVE YEARS OR MORE AFTER REDUCTION

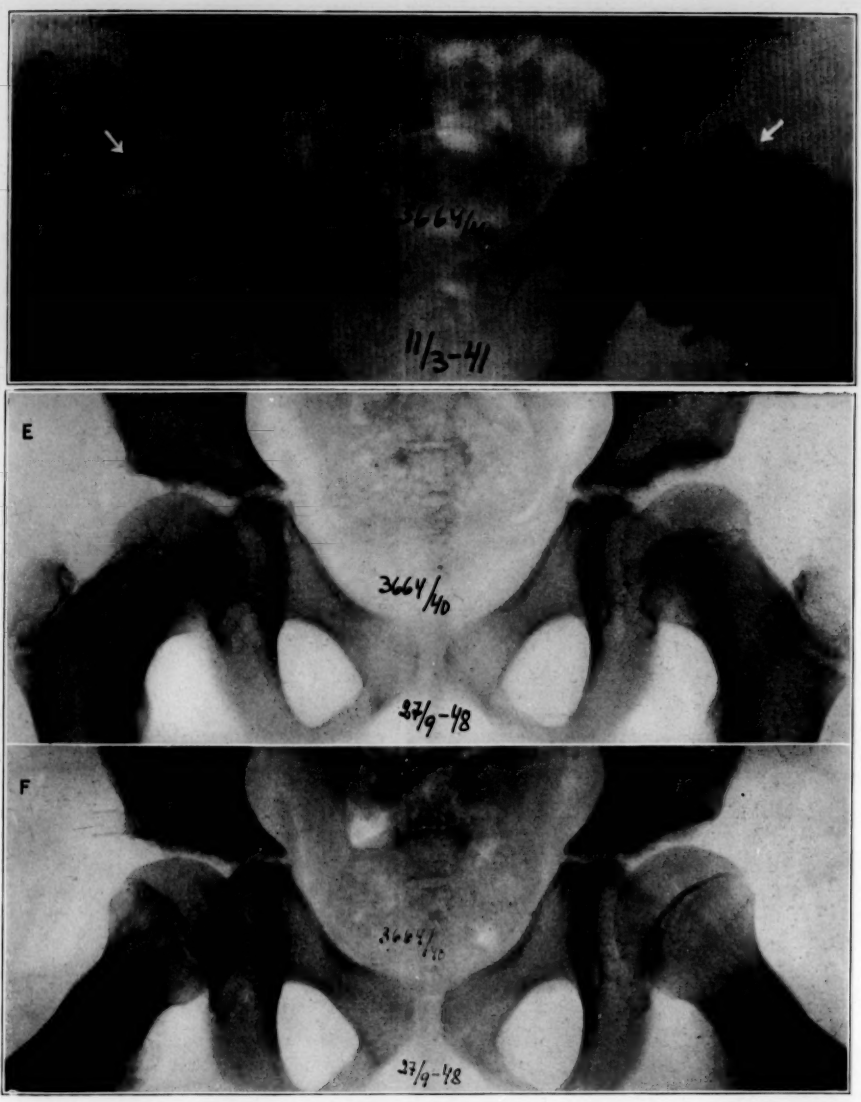
Group		No. of Hips	Per cent.
I	Well developed hip joints	24	33.3
II	Moderate deformity of the femoral head, neck, or acetabulum in otherwise well developed joint	7	9.7
III	Dysplasia, but not subluxation	14	19.5
IV	Subluxation	27	37.5
V	Femoral head articulating with secondary acetabulum	0	0
VI	Redislocation	0	0
Total		72	100.0



R FIG. 4 L

A, *B*, and *C*: No. 3664/40, September 4, 1940. The patient was a girl, aged one year and six months, whose right hip was normal. The left hip showed complete dislocation, with a small femoral head and an interposed limbus. After closed reduction the left hip showed the presence of a soft-tissue barrier with a large pool of dye in the proximal part of the acetabulum.

twelve at the time of re-examination. Children have an extraordinary ability to compensate for weakness in their joints, even those of considerable size. It is not surprising, therefore, to find the functional results better than the anatomical ones. Six patients limped, but had no pain or abnormal fatigability. Only two patients suffered from both limp and increased fatigability. None of the others (about 90 per cent.) had any complaint. Seven of them, however, showed a slight reduction in mobility, generally in abduction.



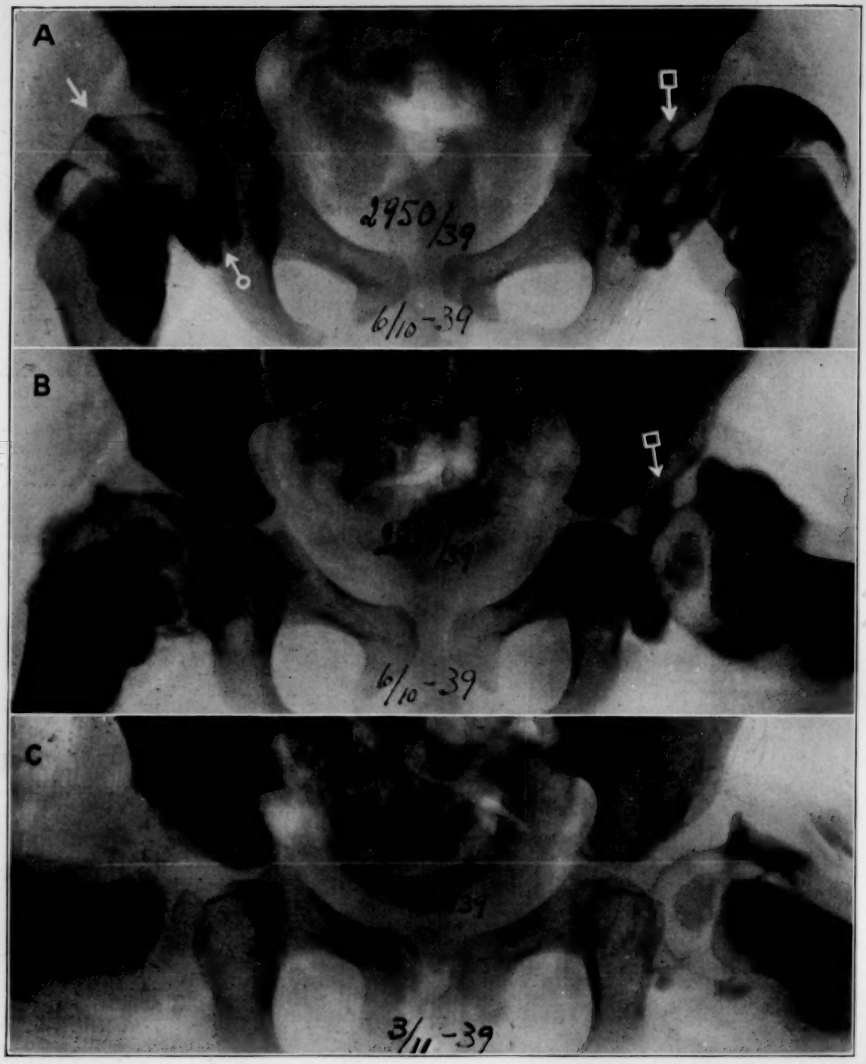
R FIG. 4 (*continued*) L

D: Arthrograms taken March 11, 1941, six months after the manipulation, showed complete reduction. The femoral head was well developed and the limbus was normally situated with its tip reaching to the Y line.

E and *F*: September 27, 1948, eight years after closed reduction. The right hip was normal. The left hip exhibited a spherical femoral head and a good acetabulum, although its roof was not so well rounded laterally as in the right hip. The result was classed in Group I.

The follow-up examination shows that, in two-thirds of the dislocated hips (Groups I, II, and III), the femoral head was still in a correct position in the acetabulum five or more years after the closed reduction. This, like the arthrographic studies, demonstrates that the soft-tissue barrier to reduction, present in most cases of complete congenital dislocation of the hip, can be overcome by closed treatment.

The most ardent advocate of open reduction, Leveuf, stated that complete congenital

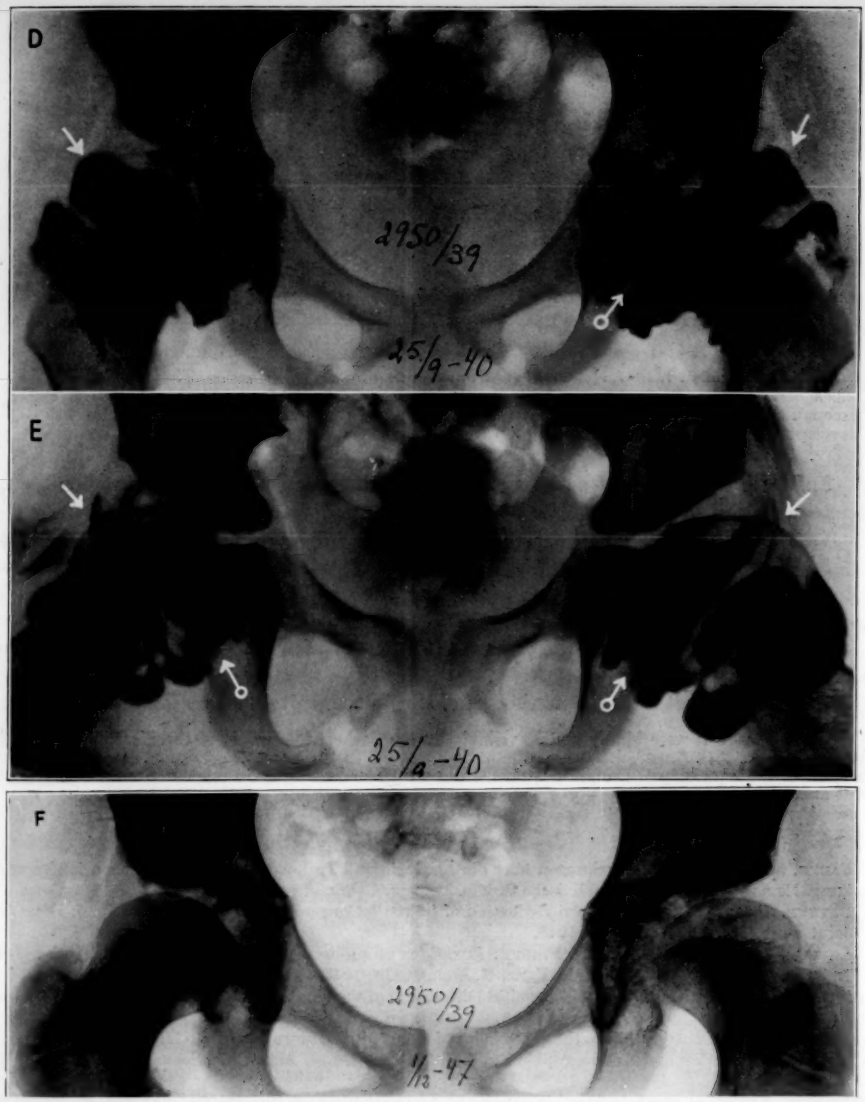


R FIG. 5 L

A and *B*: No. 2950/39, October 6, 1939. In arthrograms of a girl, aged one year and nine months, the right hip showed subluxation, the tip of the limbus was 6 millimeters above the Y line, and there was a pool of contrast agent in the acetabular floor. The left hip showed complete dislocation, an inserted limbus, and a fairly wide capsular tube. After closed reduction on the left side, the limbus was inserted between the femoral head and the ilium, and there was a large contrast pool in the acetabular floor. Five days later, on October 11, closed reduction had to be performed again on the left side because of redislocation. The course thereafter was uneventful. Both hips were treated.

C: November 3, 1939. Arthrographic study of the left hip, four weeks after the first reduction, showed that the head had pushed into the acetabular floor, where there was no longer any contrast medium. The limbus was developing laterally.

dislocation of the hip could never be properly treated by closed reduction[2]. Both the arthrographic studies and the follow-up examination of the present series fail to corroborate the statement of Leveuf.



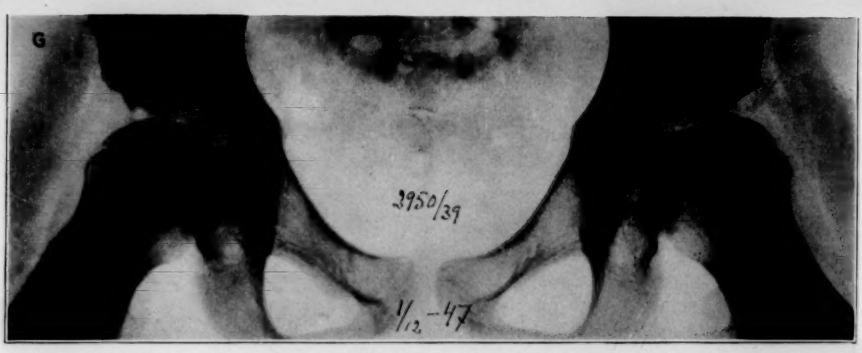
R FIG. 5 (*continued*) L

D and *E*: September 25, 1940. Arthrograms taken almost a year after reduction showed bilateral subluxation, with the tip of the limbus 3 or 4 millimeters above the Y line. Both acetabular floors contained a pool of contrast medium, larger on the left side. The cartilaginous femoral heads were well developed; the left one was slightly larger than the right.

The investigation described has shown that:

1. In the great majority of cases of complete congenital dislocation of the hip, soft tissue is interposed between the femoral head and acetabulum immediately after reduction.

2. The soft-tissue barrier is gradually overcome if the head is kept against the acetabulum.



R FIG. 5 (*continued*) L

F and *G*: December 1, 1947, eight years and one month after closed reduction. The right femoral head was spherical, articulating with a well developed acetabulum. The left femoral head was well developed except for slight flattening centrally, visible in Lauenstein's position. The left acetabulum was well developed. Both hips were classed in Group I.

3. The interposition of soft tissue had no bearing on the outcome in these cases. Thus, in itself, it does not indicate open reduction.

4. The reduction is greatly stimulating to the growth and development of the joint.

5. When the described principles of treatment were followed, the late results of closed reduction of congenital dislocation of the hip were sufficiently good to justify further work along these lines.

6. Open reduction should be reserved for the very few cases in which closed reduction is unsuccessful.

7. Closed reduction is the method of choice in congenital dislocation of the hip joint.

NOTE: The cases were kindly made available by the Orthopaedic Clinic of the Karolinska Institute (*Norrbacka-Institutet*), Stockholm, where the author assisted in their treatment during the years 1937 to 1940, under the leadership of Professor Waldenström. Professor Friberg and Professor Knutsson have given great assistance.

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CONGENITAL DISLOCATION OF THE HIP *

Part I. Method of Grading Results

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Because congenital dislocation of the hip cannot be reproduced in the experimental animal, its problems must be approached by studies of adequate numbers of patients, observed for a sufficient period of time to justify significant conclusions. An evaluation of all the forms of treatment in use at present is far beyond the facilities of even the largest clinics. The experience of many clinics must, therefore, be pooled.

A study of the results in adults of any particular treatment of congenital dislocation of the hip has the advantages of hindsight. Poor results are just as informative as good results, if the cause of the failure can be determined accurately.

A series of forty-four cases of congenital dislocation of the hip (fifty-eight hips), treated at the New York Orthopaedic Hospital by open reduction, have been followed until the patients reached adult life, and the results have been evaluated. These findings will serve as the basis for a report, divided into three parts, of which this is the first part.

A critical evaluation of the actual end results of operative procedures on weight-bearing joints should coincide with the termination of ambulatory life. Such results are seen rarely, if ever, in groups large enough to justify conclusions. However, it has been made clear by many investigators that those abnormal conditions which exist prior to the termination of growth may cause basic changes in the involved structures; these basic changes cease progressing with the cessation of growth. Nevertheless, secondary attritional and degenerative changes continue to develop as the result of these basic changes as long as stress is applied to the structure, as in scoliosis or severe genu valgum.

Evaluation of results is dependent upon the accuracy and scope of the method used, and a comparison of the results in different groups of cases is dependent upon a system of grading which can be used by different observers in various clinics with a relatively small margin of error.

If the changes in the basic mechanics of the hip joint, which occur in association with congenital dislocation of the hip, could be accurately and completely tabulated in the various stages of progression, a means would be available, not only for a study of the progress of an individual hip over a long period, but also for the comparison of different hips and for an evaluation of different methods of treatment. A perfect method of grading would eliminate the personal factor, both in the patient and the observer, so that the same conditions reviewed by any trained observer would receive the same grade. No such system has been found in the literature, nor could one be devised.

Many studies of the results of treatment of congenital dislocation of the hip have been made, but to date no two observers have used a common system of grading which has not been subject to considerable variation of interpretation by each. Therefore, one observer in unable to profit fully by the experience of another. The diversity and quantity of methods used in the study of congenital dislocation of the hip are indicative of the importance of the problem of grading the results and the failures of all the methods in meeting certain basic criteria. One has only to engage in the problem to recognize the difficulty of reducing to figures and tables the many variables in such a way as to avoid distortion of the facts in any individual case and to permit exact duplication by another observer.

The Germans, most prominently represented by Hilgenreiner and later by Faber,

* Read at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 18, 1949.

described useful objective roentgenographic measurements to determine the degree of subluxation in infancy. These measurements were applicable, however, only to the three years before the capital epiphysis became fully developed, and were subject to marked variation when the position of the hip was changed during roentgenography. Putti, in 1934, realizing the inaccuracy of pooling the symptomatic, physical, and roentgenographic findings into a common denominator, gave to each patient a "functional" grade, combining the symptomatic and physical findings, and an "anatomical" grade, based entirely upon roentgenographic findings. The criteria upon which the grading was based were indefinite, however, and could be applied only by those who had worked personally with Putti. A much larger group of observers have made no pretense of documenting their findings, but have reported their results in such terms as "perfect", "good", or "fair". The evidence was presented only by illustrations of selected cases. A single observer may remain fairly consistent in the use of non-specific gradings, but different observers vary widely in their application of such a method.

Wiberg, in 1939, published a monograph in which he described a measurement of the femoral head-acetabular relationship in adult hips, which he called the CE angle. In 1941, Severin published a complete follow-up study of 417 hips in which the dislocation had been treated by closed reduction; he followed the patients from five to twenty-seven years. Utilizing the CE angle of Wiberg, he divided the anatomical and roentgenographic findings into six groups, clearly differentiated by specific criteria; however, the standards apply only to hips which are mature or are near maturity. Like Putti, Severin graded the functional results separately. The standards which he used for function are difficult to apply to individual patients, since one encounters more combinations of pain, limp, and restriction of motion and activity than are provided for in his outline.

The system described here was devised, first, to include a large number of separate findings and, second, to include only those factors which were considered basic and effective at *all* stages in the development of the joint. The system can be used independently by other observers, and affords a high degree of accuracy and comparative value. The evaluations of *symptomatic* (subjective) findings, *physical* (objective) findings, and *roentgenographic* (anatomical) findings are graded separately on the basis of a percentage of normal, each symptom and sign being allotted a rational, although admittedly debatable, percentage of the total. The personal variations in evaluating pain, for example, are included in the symptomatic rating only, which is, therefore, the most inaccurate. The grading of the physical findings can be standardized fairly accurately, so that the results of various observers closely approximate each other when applied to the same patient. The roentgenographic standards are based for the most part on definite, although easily

TABLE I

GRADATIONS OF SEVERITY OF SYMPTOMS

Grades of Severity	Pain	Fatigue	Activity
None	None	None	No restriction
Intermittent	Present on exceptional occasions	Present with severe exertion only	No restriction
Mild	1. With prolonged weight-bearing 2. Present with weather changes	Difference in hips on exertion or, in bilateral cases, fatigue which can be localized to hips and thighs at end of day	Loss of facility in games or complicated movements
Moderate	Steady with prolonged activity	Frequent rest required	Non-essential ambulation is avoided
Severe	Severe even with mild activity	Rest required every ¼ mile	Daily routine rearranged to avoid ambulation

TABLE II

GRADING OF SYMPTOMS

	None (*Per cent.*)	Intermittent (*Per cent.*)	Mild (*Per cent.*)	Moderate (*Per cent.*)	Severe
Hip pain	30	22.5	15	7.5	0
Back pain	10	7.5	5	2.5	0
Fatigue	20	15.0	10	5.0	0
Activity	40	30.0	20	10.0	0
Total	100	75.0	50	25.0	0

determined, measurements. Each measurement applies to any stage in the development of the hip, and the normal values tabulated have been both selected from the literature and checked by the authors from a series of normal roentgenograms.

No roentgenographic measurement is a mathematical certainty, because slight positional variations affect the readings, and films made in various clinics or at widely separated periods in the same clinic nearly always show positional variations. Careful measurements, however, will give a grade which is considerably more accurate than a compilation of all available facts into a general clinical impression. Efforts to oversimplify make the entire evaluation useless as a comparative standard.

Age Groups Studied: Each hip was graded roentgenographically in four periods: *before reduction, two years after reduction, at puberty,* and *in early adult life,* after all hip-joint epiphyses had closed. The hips were not graded symptomatically and physically in the early periods, because all essential data were not obtainable from the records in each period in every case.

Symptomatic rating (SR) is expressed as a whole number, representing a percentage of normal derived from totaling the grades of the four components: hip pain, low-back pain, fatigue, and activity. Each of the four components is divided into five gradations of severity (Tables I and II), each having a specific percentage of the total. These divisions were classified as shown in Table I. Each finding is entirely subjective. Low-back pain is included, because in the older patients this is often an important complaint.

Physical rating (PR) is also a whole number, expressing a percentage of normal and including such physical findings as are completely objective. The grades of severity, shown in Table III, are self-explanatory. It was obvious that hip motions were of primary importance, but, as they could not be evaluated singly, an index was utilized which reduced all six motions to a single figure. The index used by Ferguson and Howorth has

TABLE III

GRADING OF PHYSICAL FINDINGS

						No. of Points
Hip-motion index × 0.60						60
Limp due to hip mechanics						20
None	Intermittent	Mild	Moderate	Severe		
20	15	10	5	0		
Abductor power						10
Normal	Good	Fair	Poor	Trace	None	
10	8	6	4	2	0	
Limp due to leg shortening (Subtract 1 point for each ¼ inch of shortening)						10
Total						100

TABLE IV

GRADING OF ROENTGENOGRAPHIC FINDINGS

			No. of Points
A. Size of femoral head			
1. Normal			5
2. Less than normal		2.5	
3. Greater than normal		0	
B. Anteversion			
1. Normal (less than 30 degrees)			5
2. 30 to 45 degrees		2.5	
3. More than 45 degrees		0	
C. Shape of femoral head			
1. Normal			20
2. Slightly irregular		10	
3. Deformed		0	
D. Obliquity of acetabular roof			
1. Normal			20
Normal values: Under 1 year	30 degrees		
1 to 3 years	25 degrees		
Over 3 years	20 degrees		
(One point is subtracted for every degree of roof obliquity over the normal for that age.)			
E. CE angle			
1. Normal			50
Normal values: 6 months to 3 years	10 degrees		
Over 3 years	20 degrees		
(One point is subtracted for every degree less than normal for the age.)			
Total			100

been modified for simplicity. Our index is derived as follows, normal values being used for each motion, multiplied by an arbitrary factor indicating the relative importance of motion in each plane:

Flexion-extension	45 to 200 degrees (155 degrees) × 0.4	62
Abduction-adduction	40 to 30 degrees (70 degrees) × 0.3	21
External rotation–internal rotation	50 to 35 degrees (85 degrees) × 0.2	17
		100

Contracture in any plane proportionately reduces the grade for that plane. For example, a flexion contracture of 30 degrees would permit a range of 45 to 150 degrees or a total of 105 degrees, which, multiplied by 0.4, gives a rating of 42 for that plane, or 20 points below normal.

Roentgenographic rating (RR) is derived from an evaluation of the factors shown in the roentgenogram which are thought to contribute basically to the function of the hip, and which would be related to progression of symptoms through attritional or degenerative changes. However, in order that the comparison of hips in patients of various ages or the same hip at various stages of development may be most valuable, osteo-arthritis is omitted as a factor in grading. Also omitted are a number of minor factors possibly having some influence on the outcome, but the evaluation of which involves technical errors that would invalidate the entire grade. A score of such measurements, suggested in the literature, were recorded and discarded.

Hence a hip with severe arthritis secondary to a previous avascular change might receive a high grade, if the basic structure of the joint remained good. Therefore, when it

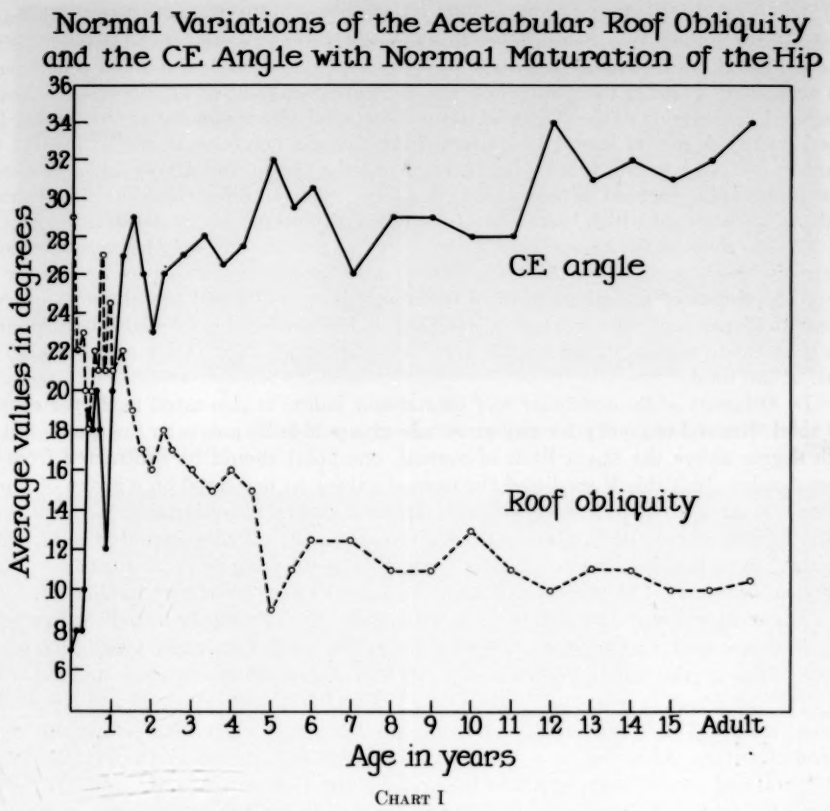

CHART I

is thought that the degenerative changes are sufficient to influence function (that is, moderate or severe arthritis), a symbol (A) is placed after the roentgenographic rating. In computing the final results, the grade of hips so marked is reduced by 50 per cent. Omitting arthritis as one of the basic factors does not nullify the usefulness of the grading, however, because, as will be seen in many of the tables in Part II, much information can be gained from comparing these basic factors, the degenerative changes being disregarded for the time being.

Basic Factors

The factors considered basic are as follows (Table IV):

A. *Size of the Femoral Head or Capital Epiphysis:* Three sizes are noted,—normal, greater than normal, and less than normal. Only the obvious departures from normal were graded, because only the two extremes would seem to have much effect on the hip mechanics. The size of the femoral head is given a rating of 5 per cent. of the total.

B. *Anteversion* (femoral torsion) is difficult to measure accurately, and its relation to recurrent dislocation is still debatable. When severe, it seems to predispose to resubluxation, and thus has a direct bearing on the subsequent development of the hip. It was given a rating of 5 per cent. of the total. In this series, all estimates of anteversion were made at the time of open reduction and were probably more accurate than other methods available until recently. The usual method of estimating anteversion roentgenographically was to take two anteroposterior films of the hips and pelvis, one with the patella forward

and the other with the limb in full internal rotation. Normally the neck-shaft angle varies only slightly in these two views (depending somewhat upon the age of the patient). When anteversion of more than 45 degrees is present, however, there is a marked difference in the neck-shaft angle in the two views, but the actual amount of anteversion cannot be measured. Estimation of the degree of anteversion clinically is equally as inaccurate. It is based on the degree of internal rotation of the femoral condyles when the greater trochanters are held in the transverse plane. Recently Crane and Ryder have devised a roentgenographic method of measurement which seems to offer considerable accuracy: it also gives a record which has some advantage over fluoroscopic methods.

C. *The shape of the femoral head* is considered important, not only because any asymmetry obstructs motion and enhances attritional changes, but also because during the age of development a malformed head will result in a malformed acetabulum, and vice versa. If 75 per cent. of the head is spherical, it is considered only slightly irregular; if less than this is spherical, the head is considered deformed. The rating given was 20 per cent. of the total.

D. *Obliquity of the acetabular roof* (acetabular index) is also rated as 20 per cent. of the total. Normal obliquity for any given age group adds 20 points to the grade, but for each degree above the upper limit of normal, one point should be subtracted from the normal value. In Table V are listed the normal values, as measured on a group of hips of patients of all ages which in every respect appeared normal in conformity. Larger samples of the various ages are desirable, but those given are statistically significant. The estimated standard deviation is listed to provide a means of estimating more accurately the individual distribution. The normal variations at different ages are shown in Chart I.

The technical errors associated with this measurement are easily remedied. In a pelvic film, incorrect centering of the roentgen tube over the pelvis may cause a variation of ± 2 degrees. The overlay can be placed incorrectly unless the roentgenogram is marked with a dot at points *E* and *D* (Figs. 1-A, 1-B, and 1-C). Point *D* is easily located in an acetabulum before closure of the triradiate cartilage, at the lower tip of the iliac component of the articular surface. After fusion of this cartilage, point *D* is placed at the junction of the horizontal and vertical components of the acetabulum. Figures 1-A, 1-B, and 1-C illustrate the method of measuring the angle of obliquity at different ages.

Table V and Chart I depict the marked fluctuation of the average normal acetabular obliquity in the first year, accounted for by irregular rates of ossification of the cartilaginous roof. A steady decline is noted in the obliquity, which is quite rapid during the first three years. From three years to adult life, the average obliquity dropped only 5 degrees. The angle consistently measured from 1 to 4 degrees less in the male for various ages, but a separate tabulation would serve only to complicate the grading without adding materially to its accuracy.

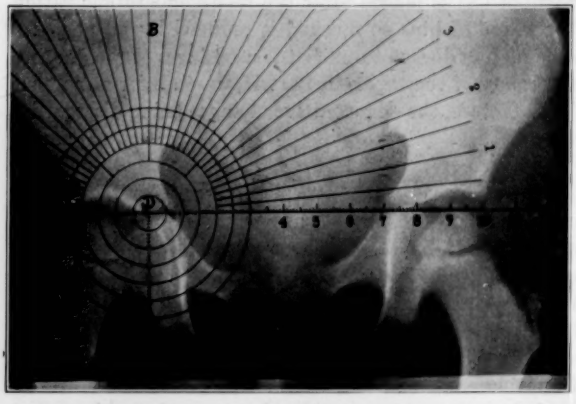

FIG. 1-A

Measurement of roof obliquity at different ages.

Fig. 1-A: The overlay is centered over the lower iliac tip on the acetabular surface (*D*), with line *A* in the horizontal plane of the pelvis. The radiating line passing through *E* indicates the obliquity, which is 10 degrees in the illustration.

If to the normal variables already mentioned is added the probability of a technical error in measurement, it

FIG. 1-B

The obliquity in this abnormal hip of an eight-year-old child measures 38 degrees, as compared to 18 degrees on the normal side.

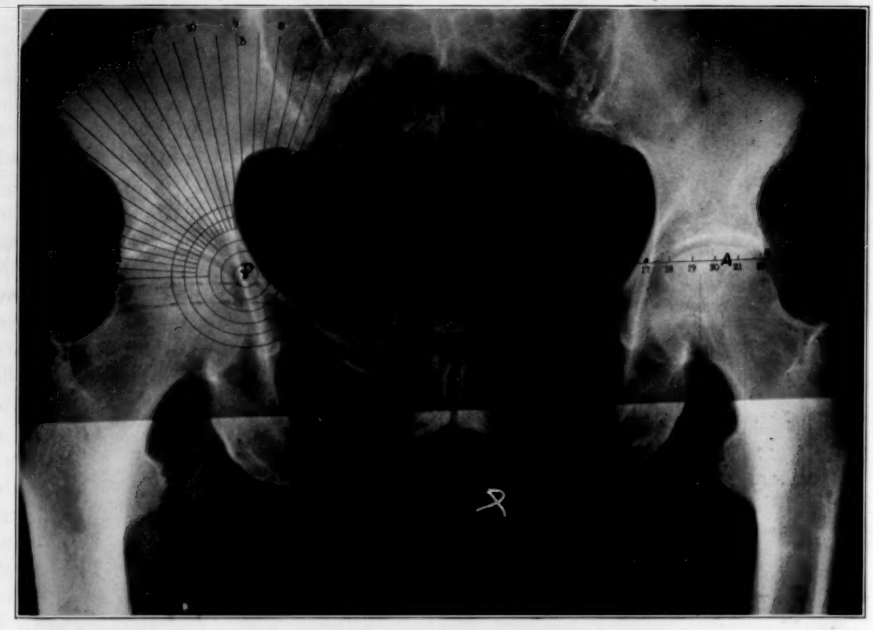

FIG. 1-C

The overlay is centered over *D*, which is the point of intersection of the horizontal and vertical components of the acetabulum. The obliquity is 6 degrees.

becomes apparent that a single figure cannot be chosen which would differentiate the normal from the abnormal in each case. However, to use this measurement in the grading of a hip, a definite point must be chosen above which one must assume that abnormality exists. No appreciable error in computing the grade of the hip will result, provided a wide margin of normal fluctuation is allowed. Therefore, for the various age groups, the following upper limit of normal has been chosen: under one year, 30 degrees; between one and three years, 25 degrees; and from three years to adult life, 20 degrees.

E. *The CE angle* of Wiberg is allowed 50 per cent. of the total roentgenographic rating. It was used by Wiberg to express in a single figure the femoral head-acetabular relationship in the adult hip. He described an overlay which, when superimposed on a film of the hips and pelvis, would indicate this relationship in degrees. Since we wished to compare this femoral head-acetabular relationship in the various stages of development of a hip from infancy to adult life, and also to compare this development with other hips, we have modified the overlay to fit our broader needs. The overlay (Figs. 2-A, 2-B, and 2-C) is superimposed on the film so that one of the concentric circles lies over or parallels the outline of the femoral head, and the horizontal line (*A*) is placed in the horizontal plane of the pelvis. Since the normal femoral head subtends a perfect circle, the central point of the circle denotes the center of rotation of the head, which maintains a constant relationship with any point on the acetabulum, irrespective of the position of the femoral head (provided a true anteroposterior view of the pelvis has been obtained). The edge of the superior acetabular roof is chosen as a point on the acetabulum which can be easily determined. The angle formed by a line passing through this edge (*E*) and intersecting the vertical line (*B*) at the *center* of the femoral head is the CE angle.

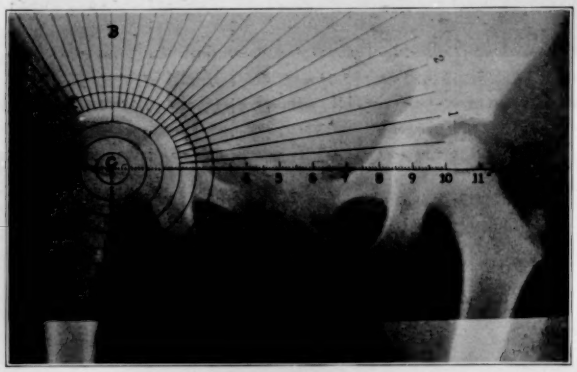

FIG. 2-A

Measurement of the CE angle at different ages.

Fig. 2-A: Measurement of the CE angle in a three-year-old child. The epiphysis is not yet symmetrical, so that the overlay is placed with the center (*C*) over the mid-point of the metaphysis and proximal to the metaphyseal edge. The CE angle is 30 degrees, as indicated by the radiating line passing through *E*.

In standardizing the use of this angle, Wiberg measured 200 normal adult hips and found that the average was 36; the range varied from 20 to 46 degrees. An angle below 20

FIG. 2-B

The CE angle is 0 degrees. Note that this angle can be measured with the hip in any degree of rotation or abduction-adduction, because, if the femoral head is circular, the center of that head will be the one point which does not change its relation to the acetabulum as a result of hip motion.

FIG. 2-C

In the adult, the overlay is so placed that one of the circular lines parallels the surface of the femoral head. With line *A* in the horizontal plane of the pelvis, the CE angle is read off at *E* and here measures 46 degrees.

degrees was considered abnormal and an angle between 20 and 25 degrees was uncertain. Severin extended the use of this measurement to hips of children from six to fourteen years of age. He found that normal hips of individuals above fourteen years of age had precisely the same measurements as in the adult, but in the age group from six through thirteen years the range extended from 15 to 40 degrees with an average of 30 degrees. For this age group Severin considered an angle above 19 degrees as normal, between 15 and 19 degrees uncertain, and below 15 degrees definitely abnormal.

Since it was found desirable for comparative purposes to utilize this measurement in children below the age of six years, the authors measured roentgenographically an additional 350 "normal" hips in children below this age. These children had no complaint related to the hips, but sought advice for various foot conditions. The average CE angle decreased from 30 degrees at the age of six years to 27 degrees at the age of three years, with a range of from 20 to 40 degrees. Therefore, the range applying to children from six to fourteen years of age can be extended downward to include those aged three years. Below three years, CE angles of less than 20 degrees begin to appear more frequently, and below eighteen months the average drops to 20 degrees or less.

A group of 215 adult hips were also measured as a means of checking the technique against that used by Severin and Wiberg. In the "normal" adult hips, routine anteroposterior films of the pelvis were taken in the Departments of Obstetrics and Urology. The position on the table in each case was the same as that used for a flat plate of the pelvis. No patient had symptoms referable to the hips. The average age of the women was thirty-five years; that of the men was fifty years. The normal variations at different ages are shown in Chart I.

The measurements checked rather closely with those of Wiberg and Severin, differing in the following respects: Of eighty-seven male hips, in none was the angle below 26

TABLE V

NORMAL VALUES FOR ACETABULAR-ROOF OBLIQUITY AND CE ANGLE

Age (*Years*)	Age (*Months*)	No. of Hips	Roof Obliquity			CE Angle		
			Average	Standard Deviation	Range	Average	Standard Deviation *	Range
	1	30	29	4.5	18–36	7	6.49	0–26
	2	10	22	4.55	16–30	8	6.5	0–20
	3	16	23	3.94	16–30	8	10.2	0–36
	4	11	20	6.38	10–30	10	4.62	6–20
	5	8	18	2.1	16–22	19	3.5	16–26
	6	24	20	6.67	10–36	18	5.14	10–26
	7	21	22	4.23	14–30	20	5.3	10–30
	8	27	21	5.0	10–30	18	5.0	10–30
	9	18	27	5.5	16–36	18	6.04	8–30
	10	12	21	6.14	8–28	18	6.14	10–30
	11	6	25	2.39	20–26	12	5.59	6–20
1		26	21	3.52	16–30	20	5.05	10–30
1	3	20	22	4.82	12–30	21	3.75	16–30
1	6	21	19	5.28	10–30	27	4.75	18–36
1	9	11	17	3.16	10–20	29	7.57	16–40
2		15	16	4.09	12–26	25	7.5	10–36
2	3	13	18	14.3	10–26	23	5.38	20–26
2	6	13	17	6.55	10–32	26	8.93	10–40
3		13	16	2.99	10–20	27	5.95	20–40
3	6	10	15	6.5	12–22	28	6.5	20–40
4		15	16	2.89	10–20	26	4.61	20–36
4	6	9	15	2.09	10–16	27	1.39	26–30
5		8	9	2.8	8–16	32	2.8	28–36
5	6	2	11	7.17	8–16	32	7.17	28–36
6		9	13	2.69	8–16	30	4.06	24–36
7		14	13	2.34	6–14	26	4.69	20–36
8		14	11	1.76	6–12	29	4.69	22–38
9		14	11	1.76	6–12	29	2.93	26–36
10		14	13	2.34	6–14	28	3.5	24–36
11		9	11	3.35	6–16	28	4.72	20–34
12		13	10	2.99	6–16	34	6.85	22–45
13		11	11	3.79	6–18	31	6.95	22–44
14		19	11	2.7	6–16	32	4.88	22–40
15		14	10	2.93	6–16	31	4.7	24–40
Adult Males		87	9	3.2	6–16	35	6.8	26–50
Adult Females		128	13	3.7	6–20	32	6.4	20–50
Total		705						

* Estimated from the range.

degrees (Table V), whereas Wiberg found 7 per cent. below 25 degrees. However, of 128 female hips, fifteen (12 per cent.) fell below 25 degrees, whereas only 5 per cent. of Wiberg's series were below 25 degrees. None of the hips in the age group from three to fourteen years, either male or female, had a CE angle below 20 degrees, but in 1.5 per cent. of Severin's series the angle was below 20 degrees.

It must be emphasized that the many variables, all subject to some error, prohibit any fixed point of division between normal and abnormal. The acceptance of a 5-degree range of uncertainty, used by both Wiberg and Severin for questionable hips, is justified. However, in order to use this measurement as part of an over-all roentgenographic rating for a given hip, a definite standard must be followed. The authors have used a *CE angle of 20 degrees as the minimum normal value for the age of three years through adult life*, admitting that occasionally normal hips may be classified as abnormal and vice versa, but

the total grade of the hip will not be affected significantly.

Measurement of the CE angle in children below three years of age becomes increasingly difficult, because less of the epiphysis is visible on the roentgenogram. Each observer must calibrate his own method when the overlay is used in individuals below three years of age. The capital epiphysis ossifies irregularly and cannot be used to locate the center of rotation. We have found that the center of rotation of the cartilaginous head lies at a point equidistant from the two poles of the metaphyseal line, and just proximal to the metaphyseal border. The accuracy of locating this central point in a given hip is subject to a careful check. If the same hip is filmed in abduction and external rotation, adduction and internal rotation, and in a neutral position, the CE angle should check within ±1 degree in all views, since the center of a sphere should not change position when rotated around that center. The variation of ±1 degree results from minor changes in position of the pelvis, incident to altering the position of the hip. Should the overlay be centered incorrectly, the variation would be considerably more. The fluctuation of the average measurements during the first year of life (Table V) is in part due to technical error, but also indicates an actual wide normal variation. The CE angle is directly dependent upon ossification of the acetabular roof, and there is a similar fluctuation in the roof obliquity at the same age. Any normal standard applied to hips of children below one year would require such a wide range as to render the measurement useless. Such hips are, therefore, not graded. However, the use of this measurement

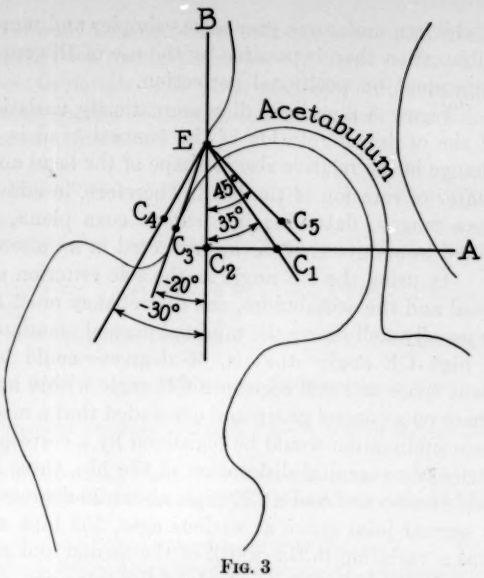

FIG. 3

Variations in the CE angle with variations in the relation of the center of the femoral head to the acetabulum.

C_1 is the normal position for the center of rotation.

C_2, C_3, and C_4 indicate varying degrees of subluxation. C_2 might also represent coxa magna.

C_5 represents a common position in coxa plana with sufficient flattening to displace the center of rotation upward.

TABLE VI

MEASUREMENT OF SUPERIOR AND MEDIAL JOINT SPACE OF THE HIP

Age Range (*Years*)	Type of Hip	No. of Hips	Average Medial Joint Space (*Millimeters*)	Average Superior Joint Space (*Millimeters*)	Range of Superior-Medial (*Millimeters*)
6 months to 5 years	Normal	17	8	7	5–10
	Subluxated	44	12	9	5–16
6 to 10	Normal	70	7	6	4–9
	Subluxated	36	14	9	5–22
11 to 15	Normal	58	8	5	4–10
	Subluxated	24	12	11	4–20
Over 15	Normal	210	8	4	3–12
	Subluxated	38	14	5	3–25

in children under one year seems simpler and more accurate in detecting small degrees of subluxation than is possible by the use of Hilgenreiner's measurements, which are highly dependent on positional perfection.

Figure 3 illustrates diagrammatically variations in the CE angle when the position of the center of rotation of the femoral head is altered by various circumstances. Any change in the relative size or shape of the head and acetabulum alters the position of the center of rotation of the head. Therefore, in addition to subluxation, conditions such as coxa magna, flattening incident to coxa plana, and the deepening of the acetabulum noted in arthrokatadysis are reflected in an altered CE angle.

In using the CE angle as the sole criterion of the relationship between the femoral head and the acetabulum, one discrepancy must be accounted for. The normal CE angle is usually well above the minimal normal standard of 20 degrees in the adult. A hip with a high CE angle—that is, 40 degrees—could have abnormal widening of the medial joint space and still register a CE angle within normal limits. Wiberg measured the joint space on a control group and concluded that a medial joint space sufficiently wide to indicate subluxation would be registered by a correspondingly low CE angle. In the authors' series of congenital dislocation of the hip, three hips presented some degree of minimal subluxation and had a CE angle above 25 degrees. To establish what might be considered a normal joint space at various ages, 355 hips were measured (Table VI). While there was a variation in the width of the medial and superior joint space at various ages, and even in the hips of individuals of the same age, the relationship between the two tended to be constant. All roentgenograms were taken at a distance of three feet. No medial joint space which exceeded 12 millimeters was found in the normal hip at any age, and the medial joint space did not measure more than 7 millimeters wider than the superior space in any normal hip. The wide range of normal for the various ages (Table VI) makes any measurement which does not fall within this range the more significant. It is doubtful, however, if this abnormal widening of the medial joint space in the presence of a normal CE angle is of any practical importance. It is not necessary to measure the joint space to recognize even minimal subluxation, since this can easily be noted by the use of the overlay. When the circumference of the femoral head and the articular surface of the acetabulum are not parallel, there has been a shift of the center of rotation laterally.

Widening of the medial joint space was not included in the roentgenographic grading, because, in 95 per cent. of the hips, measurement of the CE angle also takes this into account.

Coxa valga was not included as a factor in the roentgenographic grade, because it was thought to be definitely secondary to subluxation. Its primary deleterious effect on hip mechanics is difficult to assess. The overlay, however, is very useful in accurately determining the shaft-neck angle (anteroposterior roentgenogram with the hip in internal rotation), by placing the central point on the intersection of the long axis of the neck and the shaft.

SUMMARY

The system of grading presented here more nearly meets the requirements set forth than have others presented in the literature. This system attempts to standardize all important findings, so that various observers can arrive at the same grade for any given hip. It makes possible a comparison of the same hip at various ages which, as will be shown in Part II, gives valuable information. Those findings of least accuracy are grouped together and do not lessen the accuracy of the whole. The physical findings are more accurate than the symptomatic observations, but they too will not be graded by two observers exactly alike, since an estimate of the degree of limp and of hip motion will vary even between two careful observers.

The roentgenographic grade depends for the most part on actual measurements which

can be checked by more than one observer and, although these measurements admittedly vary somewhat with changes in projection of the roentgenograms, it is believed that this variation can be minimized by attention to details. The same plan of grading results, with some modification of the basic roentgenographic factors, can be used in evaluating the long-term results of therapy in other hip conditions.

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DISCUSSION

FLEXOR-TENDON GRAFTS IN THE FINGERS AND THUMB

(*Continued from page 499*)

ulnar nerve at the wrist and encouraging the patient to pull forcefully on the tendon. The use of tendolysis in selected cases will sometimes be necessary, as the adhesions may be so firm that the muscles are unable to free them. The use of rubber balls, bouncing putty, or other such material has not, in my experience, proved as successful as the wooden block, described by Dr. Bunnell, or a partially used bar of soap.

I have had very discouraging results in attempting to reconstruct pulleys, and prefer to use the remaining pulley whenever possible. I would like to have Dr. Boyes explain a little more fully what he means by excision of all the remaining sheath tissues, as mentioned in the last group of cases reported.

Amputation is still the operation of choice for severely damaged fingers. A graft progresses poorly through scars, and a non-functioning finger is a severe hazard for a machine operator or a laborer.

Again, I want to thank Dr. Boyes for presenting a group of excellent results in cases which, as a rule, are treated unsuccessfully by most surgeons.

DR. JOSEPH H. BOYES (closing): I would like to thank both of the discussors for their kind remarks.

Dr. Graham's question about the pulleys and the excision of the sheath can be answered in this way: We believe that the entire sheath—that is, all that is on the volar surface of the finger—should be excised. We are attempting to duplicate in these fingers the mechanism that exists on the back of the hand with the extensor tendons. I have been unsuccessful in passing the graft down through an intact sheath. For that reason no attempt is made to make new sheaths by the insertion of celluloid, stainless steel, or various types of plastics. If the pulley in the middle segment is scarred and contracted, and we are not able to put the tendon graft beneath it so that it slides freely, we do excise it and substitute for this pulley a deep subcutaneous suture of non-absorbable material. If the pulley in the proximal segment of the finger is damaged beyond hope, we excise this pulley and substitute for it a tendon graft, encircling the proximal segment subcutaneously, over the dorsum and outside the extensor apparatus.

DUAL SLOTTED PLATES IN FIXATION OF FRACTURES OF THE FEMORAL SHAFT

A Report of Eighteen Cases

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Internal fixation of a femoral fracture should establish rigidity at the fracture site, approaching that of normal bone. If this end can be attained, postoperative external immobilization may be dispensed with and the patient may be ambulatory early. The importance, from an economic standpoint, of cutting down the usual prolonged period of disability is obvious.

The method of internal fixation to be described has proved efficacious both in establishing union and in providing sufficient rigidity to permit weight-bearing, without restriction, as early as the seventh postoperative day. Two slotted plates can be used in any fracture of the femoral shaft in which internal fixation is indicated. When used alone or in conjunction with bone-grafting, they provide a satisfactory method of treating fractures with long-standing non-union and make early ambulation possible. Eighteen fractures of the femoral shaft have been treated successfully by this procedure; nine were cases of non-union.

DISCUSSION OF FIXATION BY PLATES

Successful fixation of bones by plates and screws depends primarily upon the use of suitable fixation material and upon the proper operative technique [11]. Plates of adequate size and strength and screws of good holding quality should be used. In the insertion of screws, the size of the hole is based on a close correlation between the diameter of the drill point and the root diameter and the major diameter of the screw. Proper centering of the screw in relation to the hole or slot is important, in order to avoid damage to the screw and thus to the bone threads upon which the holding power of the screw depends. If a screw is directed obliquely to the hole, the screw threads may be damaged by the edge of the plate, the bone may split, and the screw may miss the hole in the distal cortex. Many poor results of internal fixation have been due either to faults inherent in the fixation material or to defective technique.

The usual methods of plating have certain shortcomings which are well recognized. Non-union frequently results from the relative distraction of the ends of the bone, when fragments are held apart by conventional plates. It is generally recognized that the inadequacy of fixation obtained by the usual plating methods makes some form of external immobilization necessary. The postoperative course is prolonged and early ambulation is impossible. McLaughlin and his associates, in a recent report of 200 consecutive fractures of the shafts of the weight-bearing long bones, which had been treated by open reduction and internal fixation with a single plate or screws, stated that suspension was continued in fractures of the femur until healing was sufficient to permit weight-bearing with a caliper brace. In other words, with such treatment, activity is very much restricted for two to four months. Full activity is not resumed for five to eight months. McKeever, in reporting forty-seven war fractures, noted that, following plating, the average total period of protection needed before full weight-bearing could be resumed was 266 days.

In an effort to overcome the objectional feature of distraction, associated with the use of conventional plates, a slotted type of plate came into use [3, 4, 5, 12]. When the screws are inserted in the part of the slot distal to the fracture line and are not seated tightly, slotted plates permit longitudinal impaction of the fragments. It is possible to obtain ap-

proximation of the fragments at the time of reduction and, upon the resumption of weight-bearing, the bone ends are kept in continuous contact. Physiological impaction of the fragments is maintained and union is thereby stimulated.

The slotted plate designed by Townsend and Gilfillan is of light construction; although it is easily molded to the contour of the bone, it tends to bend easily. The slotted plate designed by Eggers is rigid, flat, and has two long slots. Eggers advocates loose internal fixation for contact, and depends upon external support for immobilization. It is the customary practice to use a single slotted plate of the type designed by Townsend and Gilfillan or by Eggers; the fixation obtained is much less rigid than that established by two plates.

In an effort to obtain more rigid fixation than is afforded by a single plate, two conventional plates have been used [1, 2, 6, 10]. The usual method consists in applying the plates on opposite sides of the bone. There is danger of the development of aseptic necrosis when this method is used, since the bone is held as in a vise and fixation depends upon the pressure of the plates against the opposite sides of the bone. Adams and Coonse, in using two plates applied in this manner, noted that six of eight cases showed definite aseptic necrosis as the result of torsional strain and lateral compression. Mumford reported success in treating twelve fresh fractures of the femoral shaft by the application of two conventional plates, one on the anterior and one on the lateral cortex. After operation, the extremity was immobilized in a Thomas splint with Pearson attachment.

Methods incorporating the principles of both the slotted plate and dual plating, as in the technique to be described, have been used by Wenger and by Linquist. Wenger applied two slotted plates on opposite sides of the bone in a fracture of the femur and in a long-standing fracture of the tibia. Both patients were able to bear weight by the fifth postoperative day, and the fracture of the femur healed in two months. Wenger's method requires special equipment and a special technique, and after operation further impaction of the fragments cannot be obtained. There is also a danger of mechanical constriction of bone with this form of treatment.

Linquist's method, consisting in the application of two slotted plates of the Townsend and Gilfillan type, one on the anterior and one on the lateral surface of the bone, is similar to the method to be described here. It differs in that plates of light construction

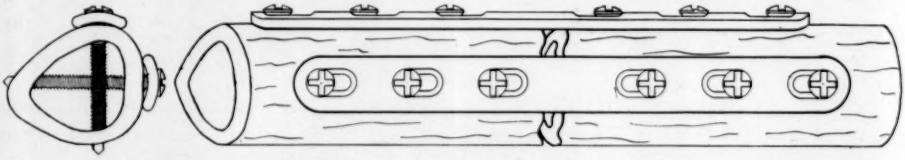

FIG. 1

Diagrammatic illustration of dual-plate fixation.

are used and the screws are seated tightly. Hence, further impaction is not obtained during weight-bearing. Linquist does not advocate early weight-bearing, although the patient may be ambulatory with the aid of crutches within two weeks after the operation. Full weight-bearing is not regained in the average case for three and one-half months. The successful use of the method in ten fresh fractures of the femoral shaft led Linquist to suggest the suitability of the method for routine use in treating fractures of the shaft, except severely comminuted fractures.

INDICATIONS FOR USE OF DUAL SLOTTED PLATES

Dual slotted plates are recommended for adults, but their use is seldom, if ever, indicated in children. The application of two slotted plates is not proposed as the routine

treatment of fractures of the femur; rather, the method is advocated only for fractures in which internal fixation is indicated. It is applicable to fractures that require operative treatment because of malposition, malunion, non-union, or a bone defect for which bone-grafting is necessary. The method may also be considered for any fractures of the femur in which open reduction is the treatment of choice. The procedure may be elected by the surgeon for special cases in which early rehabilitation is desirable.

In the authors' experience, the method has been used for the most part in long-standing fractures of the femoral shaft, after conservative methods of treatment had proved inadequate; or after operative procedures, consisting in bone-plating with or without an accompanying bone graft, had failed. In some instances, several attempts at operative repair had been unsuccessful. In one case in which fractures of the tibia and fibula had occurred in the same extremity as a femoral fracture, dual slotted plates were used successfully in both the tibial and femoral fractures.

OPERATIVE TECHNIQUE

The plates are made of stainless steel 18–12 SMo. The length of the plate varies with

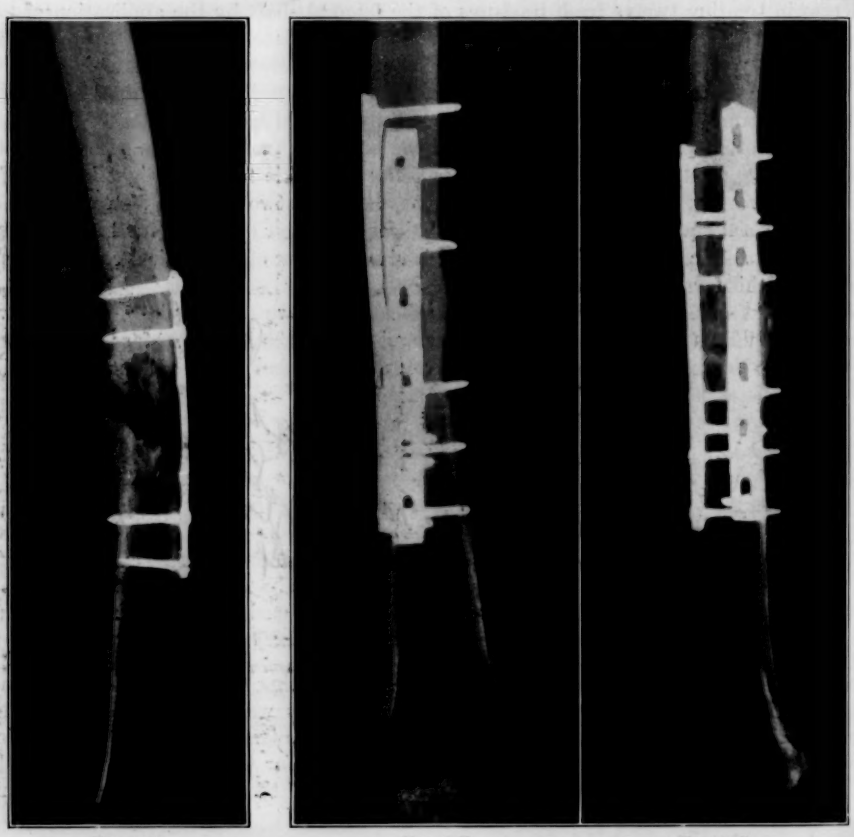

FIG. 2-A FIG. 2-B FIG. 2-C

Fig. 2-A: Case 1. J. G. Appearance of fracture twenty months after injury, following unsuccessful treatment by double spica, single-plate fixation, and a second operation supplementing plate with iliac-bone graft.

Figs. 2-B and 2-C: Postoperative views eight months after dual slotted plating (without bone graft), showing firm union. Full weight-bearing without a brace was started on the eighth postoperative day. (Two screws used in previous treatment had broken and remained in the bone.)

the type of fracture; except for an unusually long or comminuted fracture, a plate six inches long is adequate. The curve of the plate conforms to the contour of the bone, the radius of the curve being slightly less than that of the cortex. Thus the edges of the plate are in contact with the bone, so that any lateral strain on the screws is eliminated. Each plate is fitted with multiple slots, the six-inch plate having six slots (Fig. 1).

The screws are also made of 18–12 SMo steel, of the same hardness as the plates. The points are self-tapping with a pilot point, and the head is of the cruciate type [11]. The head of the screw is tapered to conform to the corresponding shape of the countersink in the plate. The proper length of the screws is determined by a measuring device.

Holes are drilled with a non-breakable drill of proper diameter for the screw,—that is, a diameter of 0.110 inch (No. 35 drill). A drill guide, which accurately fits the slot, is used to ensure proper centering of the screw in relation to the slot in the plate.

The application of the plates is as follows: After exposure of the fracture site, the fragments are reduced and held in position by means of a clamp. The first plate is applied longitudinally on the anterior or lateral surface of the bone and is held in place. Holes are drilled at the distal point of the slots at both ends of the plate, and screws are inserted and made moderately tight. Before the remaining screws are inserted, the second plate is adjusted to the anterior or lateral surface of the bone, as the case may be, at right angles to the first plate. The screws are then inserted in the end slots of this plate. There should be no crowding of the plates; they should not touch each other; and the second plate

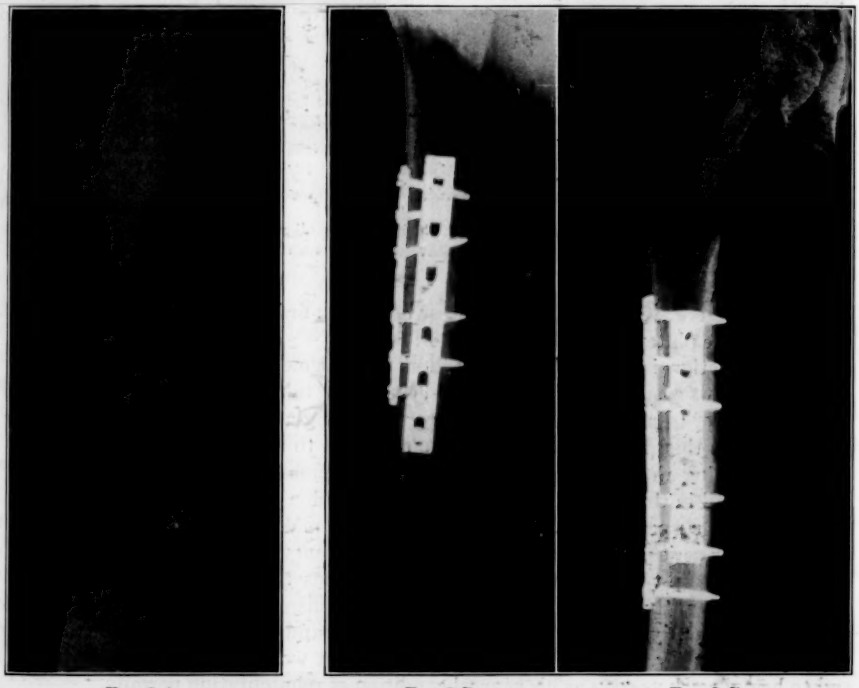

FIG. 3-A FIG. 3-B FIG. 3-C

Fig. 3-A: Case 9. D. L. Appearance of fracture five months after injury. Treatment had been by skeletal traction. The case was complicated by fractures of the opposite tibia and acetabulum, an open fracture-dislocation of the sacro-iliac joint, multiple wounds, colostomy, and severe hepatitis.

Figs. 3-B and 3-C: Postoperative views six months after dual plating (without bone graft), show firm union. Full weight-bearing without a brace was started on the eighth postoperative day. (*Photograph from Veterans Administration Hospital, Washington, D. C.*)

FIG. 4-A

FIG. 4-B

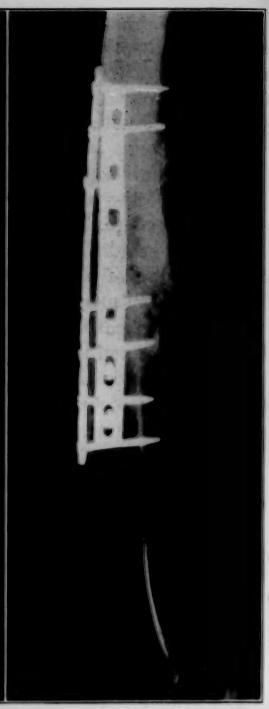

FIG. 4-C

Fig. 4-A: Case 15. M. N. Roentgenogram showing non-union, seven months after treatment by skeletal traction and double spica.

Figs. 4-B and 4-C: Seven months after dual plating and application of iliac-bone graft, union was firm. Full weight-bearing without a brace was started ten days after operation.

should be staggered, either slightly above or below the first plate, so that the screws passing through the plates do not hit each other.

The reduction is checked carefully, and the fragments are impacted slightly. The remaining screws are inserted in both plates, care being taken to use shorter screws, if there is any danger of transfixing the fragments or of hitting another screw. All the screws are tightened, and then loosened about one-quarter turn to permit further impaction of the fragments during weight-bearing. This impaction increases the rigidity of fixation. The wound is closed in the routine manner and a compression bandage is applied.

As a rule, suspension is used for a few days to make the patient comfortable. One patient in this series, however, was up in a chair twenty-four hours after the operation. Unrestricted weight-bearing with the aid of crutches may be started as early as the seventh postoperative day. Crutches should not be dispensed with until the quadriceps muscle is sufficiently strong to fully extend the knee, and the patient feels confident of its supportive capacity. The patient may return to light work in approximately one month and to heavy work as soon as his general condition of rehabilitation permits.

MERITS OF DUAL SLOTTED PLATES

In the authors' opinion, the advantages of this method outweigh any objections which might be raised because of the necessity for greater exposure of bone, increased operating time, or the introduction of more metal.

FIG. 5-A

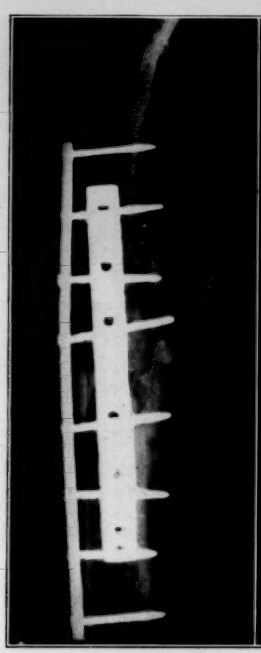

FIG. 5-B

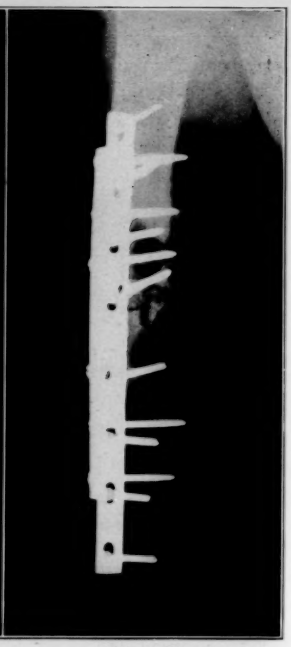

FIG. 5-C

Fig. 5-A: Case 16. J. Q. Appearance of fracture three months after injury, following treatment by skeletal traction.

Figs. 5-B and 5-C: Four months after dual plating and application of iliac-bone graft. Patient was in bed two weeks; full weight-bearing was resumed after three weeks. He returned to full military duty four months after operation.

By the use of dual slotted plates, the strength of fixation approaches, or possibly exceeds, that of normal bone. Such rigidity is obtained by fixation in two planes, by impaction of the fragments at operation, and by further impaction with weight-bearing. At the same time, there is no constricting effect on the bone. Such rigidity cannot be established by a single plate or by a plate and transfixing screw. When two conventional plates with round screw holes are used, it is not possible to obtain additional impaction during weight-bearing.

The freedom from postoperative external immobilization—such as traction, plaster casts, splints, or braces—afforded by the absolute fixation, permits the patient to bear weight as early as a week after the operation. The use of the limb in the normal way precludes stiffness of the joints. Without the handicap of a restrictive brace, the patient is able to return to work at an early date.

The postoperative course is entirely changed from that following the usual methods of treatment, which entail many months of disability. The decrease in the duration of hospitalization permits the patient to return to his normal economic status at an early period.

ANALYSIS OF CASES

This series of eighteen fractures were treated during the period from June 1947 to March 1949 *. Fourteen of the patients were males. The ages ranged from nineteen to fifty-six years, with twelve patients in the age group between twenty and thirty years.

* Since March 1949, additional cases have been treated by dual slotted plates.

FIG. 6-A FIG. 6-B FIG. 6-C FIG. 7-A FIG. 7-B

Fig. 6-A: Case 7. T. W. Roentgenogram taken two and one-half months after open fracture, following treatment by débridement and internal fixation.

Figs. 6-B and 6-C: Eight months after dual plating and insertion of iliac graft. Patient was bearing full weight after six weeks and had firm union four months postoperatively. There was complete recovery of function and a full range of knee motion.

Fig. 7-A: Case 4. M. A. Appearance of fracture sixteen months after injury, following unsuccessful treatment by two operations: (1) primary internal fixation and (2) replating and bone-grafting, ten months later.

Fig. 7-B: Postoperative view five months after dual plating and insertion of iliac-bone graft, showing firm union. Full weight-bearing was started one week after operation.

FIG. 8-A

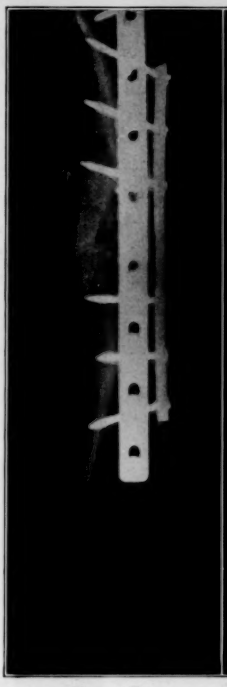

FIG. 8-B

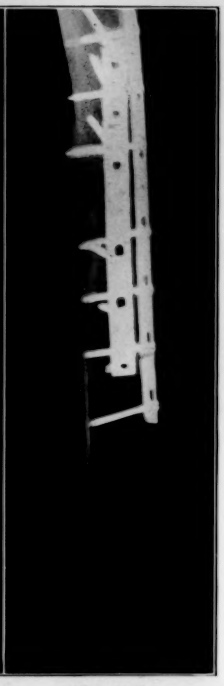

FIG. 8-C

Fig. 8-A: Case 3. L. W. Appearance of fracture thirty-four months after gunshot wound incurred in combat, and twenty months after unsuccessful plating and bone-grafting.

Figs. 8-B and 8-C: Eleven months after dual plating and grafting with iliac bone. Because of the long period of disability, this patient was kept in bed three months and then wore a brace. (Subsequent experience has shown that these precautions are not necessary.) Union was firm in eight months. Residual shortening and limitation of knee motion existed prior to final operation.

Fifteen fractures were closed and three were open. One of the latter was a fresh fracture and two were fractures of long standing in which the soft tissues had healed. Thirteen fractures were situated in the mid-portion of the femur, two in the lower third, and two in the upper third; in one case both the upper and middle thirds of the bone were involved. Eight fractures were oblique or spiral in type; eight were comminuted; and two were transverse. In over half of the cases, there had been serious associated injuries.

The method of dual slotted plating was first used in the case of J. G., on June 5, 1947. Complete non-union was present, with a bone defect in the mid-shaft of the femur. Two operations had been performed elsewhere; in one a plate had been used, and in the other an iliac-bone graft had been applied to supplement the original plate. At the time of examination, twenty months after the original injury (Fig. 2-A), there was marked mobility at the fracture site, shortening of one inch, and atrophy of the thigh of two and one-half inches. The patient refused to consider another operation which would combine plating and a bone graft; as an alternative method, dual slotted plates were used. Eight days after the operation, the patient was ambulatory and bearing full weight without a brace. Union was complete in six months (Figs. 2-B and 2-C).

The successful use of the method led to its further application. Eight additional fractures with non-union were treated by dual plating; from ten weeks to thirty-four months had elapsed before these cases came to our attention (Figs. 3-A to 6-C). Four of the patients had had operative treatment; in two cases two operations had been performed (Figs. 7-A and 7-B), and in one case, three operations (Figs. 8-A, 8-B, and 8-C).

Four of the eight patients were bearing full weight within seven to ten days after

FIG. 9-A

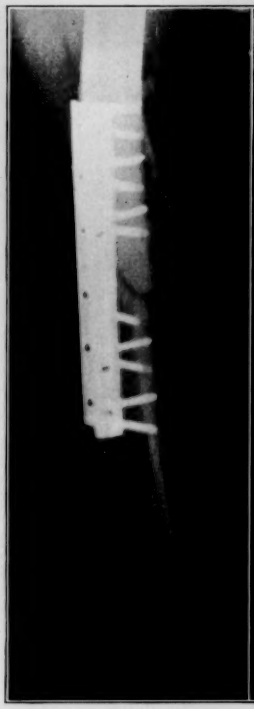

FIG. 9-B

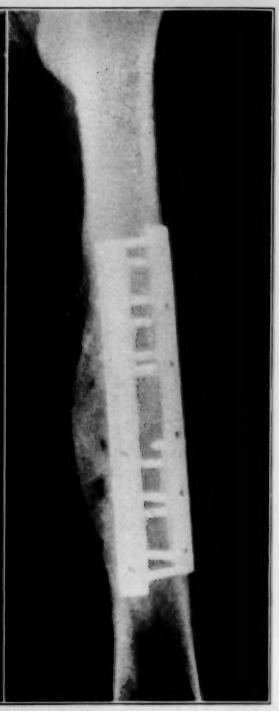

FIG. 9-C

Fig. 9-A: Case 2. S. F. Roentgenogram taken one month after closed fracture of the femur, following treatment by skeletal traction.

Figs. 9-B and 9-C: Views eight months after operation, at which time patient returned to full military duty.

dual plating; one patient bore weight in four weeks, and another in seven weeks. In the remaining two cases, weight-bearing was deferred because of associated injuries. Union resulted within four to six months in seven cases, and in eight months in the eighth case. Five of the eight patients returned to their regular occupations, including housekeeping, business, and military duty. One patient, an army officer, was retired because of partial ankylosis of the knee and shortening of the extremity, which had been present before the final operation. Union following dual plating was excellent in this case, however, and the patient is now a university student. Two other patients in the military service were also discharged, one because of shortening, and the other because of limitation of knee motion; both conditions had been present before the final operation. The results of dual plating in each case were excellent.

Five fractures with malposition were treated by dual plating, after skeletal traction was unsuccessful (Figs. 9-A, 9-B, and 9-C). All five patients were out of bed within two weeks after operation, and with one exception (Case 17) were bearing full weight within two to six weeks. Union was complete in all cases in four to six months; four patients, who were soldiers, returned to full military duty. It is too early to report on the final outcome in the fifth case (Case 17), which will be described here.

One patient in the series, a miner, was operated upon for malunion. Thirty-five years previously he had sustained a fracture of the femur, which had healed with shortening of the extremity of four inches and angulation of 35 degrees. Twenty-four hours after dual

plating, the patient was sitting in a chair; union was complete within four months. Two inches were gained in the length of the extremity by correction of the angulation.

In three fresh fractures the method was used as an elective procedure. Two of the fractures were closed and one was open. In one case there were fractures of the opposite femur, tibia, and of both bones of one forearm. This patient resumed housekeeping five months after the operation. A hand injury has prevented one of these three patients, an army officer, from returning to full duty, although union of the femoral fracture is complete. The third patient, who weighed 210 pounds, left the hospital in two weeks and gradually resumed farm work after one month. Union was complete in four months. There was marked excess of callus formation in this case, a condition not observed in the fractures of long standing.

In this series, union has resulted in all eighteen fractures. In none of these cases did a plate become loose or break, and the only plate removed was in Case 17, a civilian, in whom a late infection developed. This was the most severely comminuted fracture of the series. The complication is listed as an operative infection, but it may have been due to the patient's attempt to remove the sutures. Union progressed with roentgenographic evidence of osteomyelitis. A sinus still persists, after removal of the plates and screws, and further sequestrectomy may be required. This recent case is the only one in the series without an end result, but it is included in order to report the complication.

SUMMARY

Internal fixation of fractures of the femoral shaft by two slotted plates is advocated for the treatment of fractures in which internal fixation is indicated for malposition, nonunion, or malunion, or in which open reduction is the treatment of choice.

The report includes a series of eighteen fractures which were treated successfully by this method. The absolute rigidity and contact established by two slotted plates make it possible to dispense with external immobilization, and the patient may bear weight without restriction as early as a week after the operation.

NOTE: Seven of the cases in this series were seen on the Service of Leonard T. Peterson, George Washington University, and eleven cases on the Service of Colonel August W. Spittler, Walter Reed General Hospital.

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THE PATELLA

Its Importance in Derangement of the Knee *

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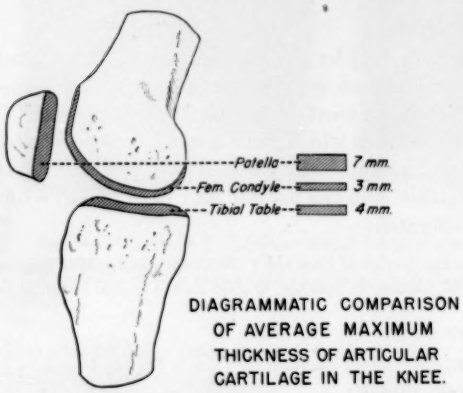
This paper is based upon a study of eighteen cases in which the patella was considered to be the primary factor in knee derangement. Twelve were due to chondromalacia, and six to hypertrophic changes.

No one, we believe, will deny that the patella as a cause of disability in the knee joint has been greatly neglected. Except for numerous papers concerning fractures of the patella, relatively little has been written concerning this important bone, which plays so prominent a part in many derangements of the knee.

Some writers go so far as to say that the knee functions just as well without a patella. However, in a recent survey by Scott of 196 cases of fracture of the patella, in 101 of which the patella had been excised, only 5 per cent. of the patients believed that the knee was normal. When one considers the size and anatomical arrangement of the patella in its relationship to the femoral condyles, it is only fair to assume that this bone does serve definite functions, first as a protection to the knee joint itself, and second, as an important part in the extensor apparatus of the leg.



DIAGRAMMATIC COMPARISON OF AVERAGE MAXIMUM THICKNESS OF ARTICULAR CARTILAGE IN THE KNEE.

FIG. 1

Herbert Haxton, of Oxford, demonstrated experimentally that the patella improved the efficiency of knee extension "by holding the patellar tendon away from the axis and thereby increasing the extending moment of the quadriceps pull". The efficiency of extension was greatly diminished after patellar excision, in spite of strong suture of the quadriceps to the patellar tendon. Therefore, in this discussion, the authors will hold to the thesis that the patella has definite functions,—namely, to protect the knee joint and to improve efficiency in extension of the knee. This conception has been preserved in the treatment we have employed with patellae which we believe are causes of internal derangement.

At birth, the patella is composed of hyaline cartilage, and usually develops from a primary center of ossification when the child is from two to five years; there is full replacement of cartilage by bone at the age of seventeen to eighteen years. The relatively thick articular cartilage over the patella, as compared to that of the femoral condyle (Fig. 1), is important, and may be a factor in some of the disabilities to be discussed here. The cartilaginous surface is divided into two facets by a vertical ridge. The lateral facet is wider and deeper than the medial one, corresponding to the difference in size and contour of the articular areas of the femoral condyles.

PATELLAR CHANGES

In the clinical evaluation of patellar changes and their relation to internal derange-

* Read at the Annual Meeting of The American Orthopaedic Association, Colorado Springs, Colorado, May 20, 1949.

ment of the knee, we must know the appearance of the average patella at different decades in life, and what degree of patellar change is necessary to produce symptoms. Bennett, Waine, and Bauer, in their worth-while monograph, have given us a good basis for evaluation of changes in the knee joint at different ages. They demonstrated that, after fifteen years of age, every individual may show some evidence of degeneration in the knee joint, and that the superficial articular-cartilage layer of the patella is the area of earliest change.

Figure 2 shows the reaction of the patella to repeated stress, strain, wear, pressure, and disturbed or abnormal joint mechanics over a period of years.

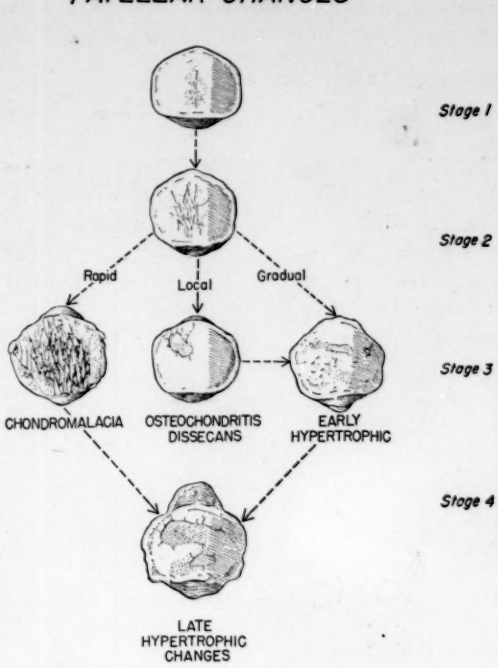


Fig. 2

Fig. 2: Patellar changes.

Stage 1: Represents the earliest articular change, usually a local softening of the cartilage, gradual unmasking of the vertical fibrils, and loss of hyaline matrix. Early fissuring or splitting of the cartilage may be seen.

Stage 2: Gradual increase in disintegration.

Stage 3: With repeated traumata, three types of changes may take place: (1) *rapid* disintegration of part or all of the articular bed in the thick articular cartilage of the young adult (chondromalacia); (2) *local* cartilage fracture (or osteochondritis dissecans), with the separation of a large single fragment of hyaline cartilage; or (3) *gradual* thinning of the entire articular cartilage, and erosion down to bone.

Stage 4: The "hypertrophic" or final stage, in which a large part of the articular cartilage has been lost, and the patella is broadened, thickened, and irregular.

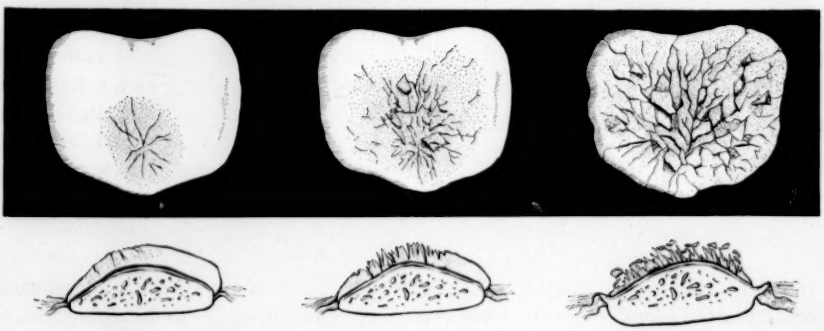

ARTICULAR CHANGES IN CHONDROMALACIA OF PATELLA
Dull, soft central area, with early fissure formation.
Deepening of fissure formation and increase in fragmentation of cartilage.
Advanced articular changes- "crabmeat" appearance of cartilage.
Loose body formation.
Synovial thickening.
Femoral condyle changes.

Fig. 3

CHONDROMALACIA

All stages of the aging or disintegrating process of the patella may be looked upon as variations of chondromalacia (Fig. 3). This term is used, however, for the more rapid fragmentation of the thick hyaline-cartilage layer in the young adult. This may appear as localized, shaggy areas of softening and fragmentation of the cartilage, or as destruction of the entire articular surface of the patella, with secondary subchondral-bone proliferation.

Stages of Chondromalacia

In 1945, the authors [3] reported that the incidence of chondromalacia as the primary cause of internal derangement of the knee was 7 per cent. of 124 consecutive knee arthrotomies. Other surgeons [9] have reported the incidence as high as 18 per cent. The relatively common occurrence suggests that the condition is not rare in the young adult. It is frequently overlooked for the following reasons:

1. While the history is suggestive of internal derangement of the knee, the physical examination is inconsistent, largely because of the difficulty in examining the articular surface of the patella.
2. Roentgenograms of the patella usually show normal findings.
3. At operation, the patella is frequently not explored adequately.

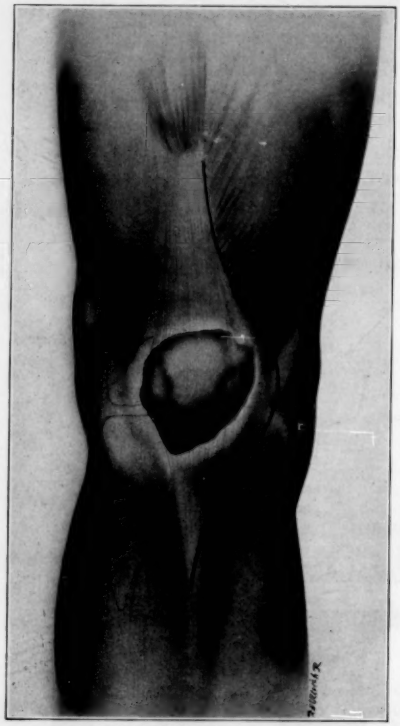


FIG. 4
Skin incision.

Mechanism of Injury

In the authors' series of twelve cases, symptoms were precipitated by recurrent strains of the knee in five instances, and by repeated direct blows on the patella in six; in one case, there was no definite history of injury.

Symptoms and Signs

These consist of intermittent pain over the anterior aspect of the knee and a momentary sensation of catching, followed by slight stiffness and moderate swelling of the joint, atrophy of the thigh, and tenderness along the medial border and the articular surface of the patella.

Roentgenographic Findings

In each of the twelve cases in which operation was performed, the roentgenograms revealed a normal patella. Osseous loose bodies were seen in the joint in three cases, and osteochondritis of the femoral condyles was evident in three.

Treatment

The form of treatment to be employed is determined by the severity and duration of symptoms in the individual case. If the symptoms are mild and cause only occasional disability, even though the diagnosis of chondromalacia may be reasonably certain, the patient should be followed carefully, given exercises to maintain strength of the quadriceps

muscles, and cautioned to avoid injury to the knee. For the patient with moderately severe symptoms, with locking or frequent catching of the knee followed by pain, swelling, and stiffness, operation is probably indicated.

The knee should be explored through a parapatellar incision and, if the lesion of disintegrated cartilage is of moderate size, complete excision of the area should be carried down to bone. A diligent search should be made for loose cartilaginous bodies. If the area of chondromalacia covers essentially the entire articular surface of the patella, or if there is marked eburnation and thickening of the patella (the final stage of the process), one of two operative procedures is indicated, — either a patellaplasty or complete removal of the patella.

Findings at Operation and Follow-up

The operative findings in the twelve cases were as follows:

	No. of Cases
Patella	
Severe changes in entire patella	3
Severe changes in central and inferior portions	3
Moderately severe changes in central portion	3
Moderately severe changes in central and inferior portions	2
Moderately severe changes in central and medial portions	1
Femoral Condyles	
Changes in lateral femoral condyle	2
Changes in medial femoral condyle	1
Loose Bodies	
Cartilaginous bodies	7
"Flecks" of cartilage	4
Calcified loose bodies	3

Abstracts of cases of chondromalacia have been reported previously[3].

Microscopic Changes

Sections of cartilage from an area of chondromalacia may show abnormal grouping or proliferation of the superficial cartilage cells, with disruption of the usual architecture. This may progress to swelling of the chondrocytes and fibrillation of the cartilage matrix, associated with loss of intercellular substance. In some sections, the cartilage degeneration failed to show any cellular response or grouping of the cartilage cells.

THE HYPERTROPHIC PATELLA

In the older adult, the patella may also be a cause of knee derangement, although there are usually associated changes in the condyles, in the menisci, and in the synovial membrane. The hypertrophy may develop following what we commonly refer to as chondromalacia of the patella; it may come after injury, such as fracture, or simply localized trauma without fracture; or it may be a part of the gradual aging process of the knee joint.

The history is that of recurrent, rather prolonged, pain in the knee, with moderate remission of symptoms over a period of weeks or months, only to be followed by recurrences, precipitated by unusual walking or standing or by additional acute injury to the knee. There may be swelling, pain, and generalized aching throughout the knee, particularly discomfort on flexion and extension. Examination usually reveals generalized thickening of the synovial lining, broadening and thickening of the patella, and associated hypertrophic changes along the joint lines. Motion is practically always markedly restricted. Pain is sometimes relieved by rest and local applications of heat, but is made worse by activity.

Characteristic roentgenographic findings are a markedly thickened patella, with hypertrophic changes at the patellar borders, and frequently associated changes throughout

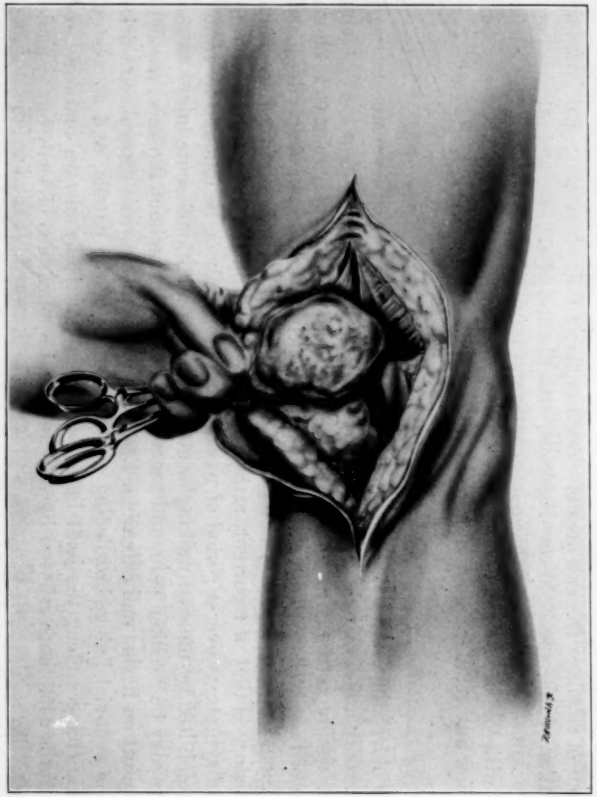


FIG. 5

The patella is turned upward and is supported in this position. This gives adequate exposure of the patella and the infrapatellar fat pad.

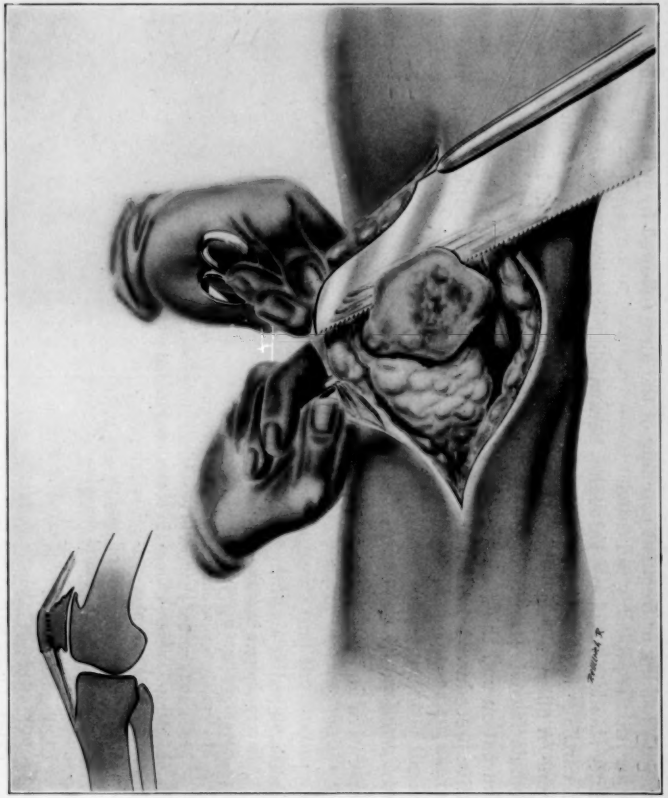


FIG. 6

Showing partial resection of the patella. The joint is walled off with moist saline sponges during this process. Inset shows approximate line of resection. The major portions of the quadriceps and patellar tendons are left intact.

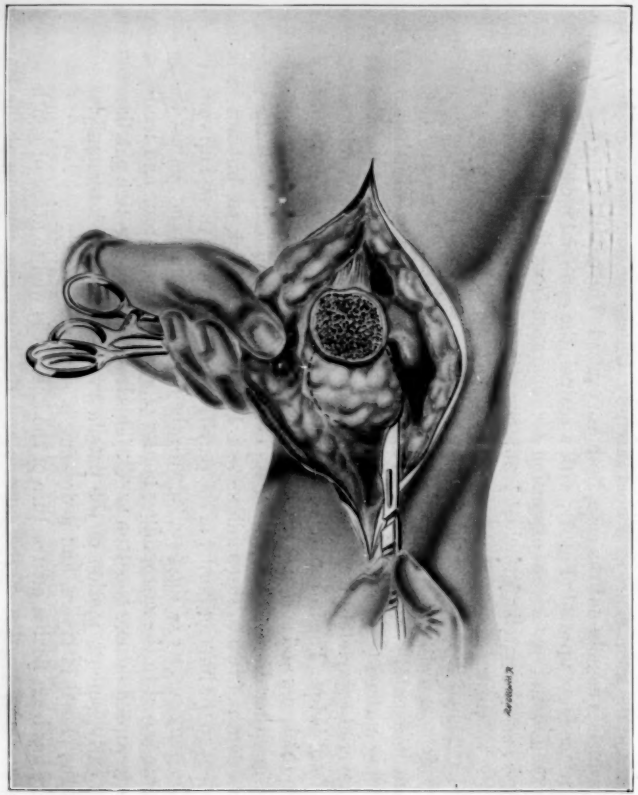


FIG. 7

Approximately one-quarter of the patella remains. The bone surface is covered by an infrapatellar flap of synovial membrane and fat pad. It is outlined by sharp dissection and is undercut back to the lower border of the patella.

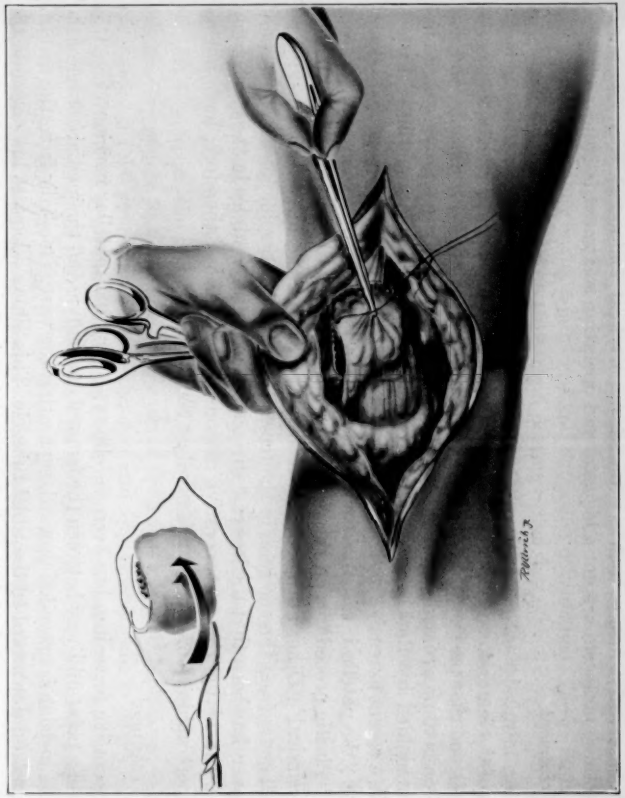


FIG. 8

The patellar surface is covered by turning the infrapatellar flap upward and sewing it with fine cotton or silk sutures to the synovial membrane and tendinous cuff of the lateral, medial, and upper borders of the patella.

the knee joint, with or without loose-body formation. Many of these patients can be improved by conservative means, such as external support, heat, and muscle exercises; but in some cases these measures are not adequate, and operative treatment is indicated.

Surgical Treatment

Keeping in mind what we believe to be the two functions of the patella—namely, protection of the femoral condyles and maintenance of efficiency in extension of the knee—we have believed that preservation of at least a portion of the patella is desirable, and that total excision is to be avoided, if possible. Excision of the markedly overgrown patella has been recommended by Berkheiser, who performed the operation eleven times. Kuhns, however, in a recent extensive review of the literature on surgery in chronic arthritis, concluded that "the patella is essential for the normal mechanics of extension at the knee", and that: "Plastic procedures on the patella seem to give a better functional result than complete removal". Other authors, chief of whom is Magnuson, have recommended removal of all spurs from the condyles in the femora in the hypertrophic knees. Our experience, however, has been that the less raw surface left over the condyles in the older group of patients, the better the postoperative response. The authors, therefore, have not removed hypertrophic spurs from the femoral or tibial condyles.

Operative Technique

Our operative procedure has been as follows: A long parapatellar incision (Fig. 4) is started from a point mid-way between the femoral epicondyle and the medial border of the patella. The incision is extended upward, separating the vastus medialis from the quadriceps tendon, and downward to the tibial tubercle. This allows adequate inspection of the anterior compartment of the joint. (All of the six joints in five patients operated upon have shown marked hypertrophic changes, particularly over the femoral condyles and about the patella. The synovial membrane was thickened and, in many cases, there have been loose cartilaginous and osteocartilaginous bodies.) First of all, then, a diligent search is made for loose bodies, and the menisci are inspected carefully. Unless the menisci are extremely well preserved, which is usually not the case, both are excised. The patella is turned so that its articular surface faces upward (Fig. 5); with a scalpel, the synovial membrane and a portion of the tendon and quadriceps expansion are separated from the superior, lateral, and inferior borders of the patella, sufficient tendinous attachment being left to maintain continuity of the extensor apparatus. As the greater portions of the quadriceps and patellar tendons are attached to the outer third of the patella, relatively little of the actual tendinous attachment is disturbed. With a handsaw or an oscillating bone saw (Fig. 6), the patella is cut horizontally and is thinned to approximately one-quarter of the normal size. The remaining surface (Fig. 7) is smaller in diameter than the original patellar surface; it can be covered completely by a flap of infrapatellar fat pad and synovial membrane, turned up from below. The infrapatellar fat pad is an excellent source for the flap, as it is adequate in thickness and surface area. In no case have we found the infrapatellar fat pad insufficient in either diameter or thickness. The flap is outlined and, with the scalpel, is incised for a depth of two to three millimeters. It is undercut back to, but not including, its attachment to the inferior border of the patella. The flap is then turned upward (Fig. 8), covering the bony surface of the patella, with the synovial membrane against the patella. The edges are sewed to the surrounding border of synovial membrane and tendinous cuff with fine interrupted sutures of cotton or silk. This leaves a very effective patellar covering, and allows early, smooth motion of the patella over the femoral intercondylar surface. The wound is closed in layers, and a dressing is applied.

If there has been flexion contracture of the knee, it is well to attempt gentle stretching of the posterior portion of the capsule and the hamstring muscles at the time the operation is performed.

Postoperative Care

Undoubtedly one of the most important problems in rehabilitation of these patients is to restore strength in the quadriceps and extension of the knee. The patient is encouraged to set the quadriceps on the second postoperative day; usually by the third or fourth day, quadriceps control is fairly well restored. If a plaster-cylinder support is used, it is usually removed on the seventh or eighth day and resistance exercises are begun both for the quadriceps and the hamstrings, in an effort to regain motion in flexion as well as in extension. On the seventh to tenth day, depending upon progress, walking is begun. At first a walker is used, and then the patient is instructed in the use of crutches. These are continued for six to eight weeks, and resistance exercises are done for six months or more. These patients continue to improve for at least a year.

Findings at Follow-up Examination

All but two of the cases of hypertrophy of the patella in which patellaplasty was performed have been followed for over two years; of these two, one was followed for eight months and one for fifteen months.

In four knees the results have been evaluated as excellent (complete extension and appreciable gain in flexion, satisfactory use of the knee, and no complaints); one knee was considered a good result (complete extension and appreciable gain in flexion, good use of the knee, but mild symptoms of fatigue and not quite normal quadriceps power); and one knee was judged a poor result (persistent pain, disability, and appreciable loss of motion).

The one important factor in the successful cases was the ability of the patient to regain active extension of the knee. This may come slowly, particularly if flexion deformity has been of long standing. In the preoperative evaluation of the case, care should be exercised in selecting the patient who is willing to work to regain a useful knee. Any evidence of a rheumatoid state should be noted, as we believe that patellaplasty is not indicated in rheumatoid arthritis.

Abstracts of Illustrative Cases

CASE 1. D. W. C., a woman, aged sixty-two, was examined on November 25, 1939. The patient stated that, for six weeks, she had had disability, pain, stiffness, and inability to straighten the knee completely. Examination revealed thickening of the knee joint, 10 degrees of fixed flexion, broadening and thickening of the patella, and a loose body, apparently lying between the patella and the femoral condyles. At operation, the patella was found to be markedly widened, and was proliferated at its borders. There were three partially attached loose bodies in the suprapatellar pouch. One, 0.5 by 1 centimeter in size, was blocking extension of the knee. Practically all articular cartilage had been worn away from the patella. A patellaplasty was performed. Six months after operation the patient was symptom-free. She had a normal range of motion in the knee and was doing her work in an antique shop, going over stairs many times a day.

Roentgenograms of this patient are not available. It was not possible for her to come in for examination, but in February 1949, ten years after her patellaplasty, her doctor stated: "The function of her right knee is perfectly normal, and there is no limitation of motion or instability. She uses her knee without any hesitation." The patient wrote: "The knee appears to be as good as it ever was. I never have any discomfort."

CASE 2. C. H., a woman, aged sixty-eight, was seen in October 1938, because of pain in the right knee. Examination revealed generalized thickening of the knee, particularly thickening and broadening of the patella, 5 degrees of fixed flexion of the knee, with further flexion to 80 degrees. She was treated with external support, exercises, and arch supports. Eight years later, the left knee was more troublesome than the right; while she was being examined, the left knee locked (Fig. 9-A). At operation on the left knee on August 7, 1946, the patella was markedly thickened and eburnated, and was overgrown in all directions. A loose osteocartilaginous body, 0.5 centimeter in diameter, was lodged between the patella and the femoral condyles, and presumably had come from the patella. A patellaplasty was done; loose bodies and both menisci were removed (Fig. 9-B). Eight months after operation, the patient was free from pain in the knee; she had complete extension, and flexion to 85 degrees. She was so pleased with the result that, on April 22, 1949, the right knee was treated in the same manner (Figs. 9-D and 9-E).

FIG. 9-A FIG. 9-B FIG. 9-C

Fig. 9-A: Case 2. Left knee, before operation.
Fig. 9-B: Left knee, after operation. Fig. 9-C: Left knee, three and one-half years after operation.

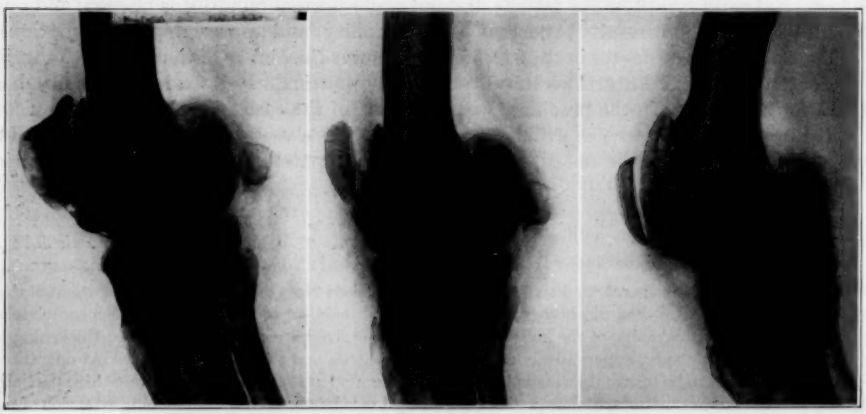


FIG. 9-D FIG. 9-E FIG. 9-F

Fig. 9-D: Right knee, before operation.
Fig. 9-E: Right knee, after operation. Fig. 9-F: Right knee, eight months after operation.

In January 1950, eight months after operation on the right knee (Fig. 9-F) and three and one-half years after operation on the left knee (Fig. 9-C), she stated that she felt "fine". She was able to do all of her own housework and shopping, as well as climb stairs and go swimming. Examination of the left knee showed no local tenderness or synovial thickening. Extension was complete, with active flexion to 60 degrees. Straight-leg raising was performed without a lag, and quadriceps power was very good. Roentgenograms showed no unusual joint changes. The right knee had no unusual joint thickening, local tenderness, or instability. Extension was complete, and there was 80 degrees of active flexion.

CASE 3. J. N. F., a woman, aged thirty-four, was seen in September 1947, because of pain and "locking" of the right knee of three months' duration. There had been no significant injury. She had difficulty in going up and down stairs, and marked discomfort on straightening her knee. Examination showed increased synovial thickening and irregularity of the joint lines; her knee extended completely, but had only 30 degrees of flexion, with frequent "catching". There was considerable crepitation between the patella and the femoral condyles. Roentgenograms showed a loose body, and hypertrophic changes were present about the joint

margins; the patella was thickened and irregular (Fig. 10-A). The patient was given a knee support, and quadriceps exercises were carried out for one year, but without benefit.

At operation on January 4, 1949, two loose bodies, 0.75 by 1.5 centimeters in size, were partially attached to the undersurface of the patella; another, unattached, was in the quadriceps pouch. The patella showed marked hypertrophic changes, with complete destruction of the articular cartilage in the mid-portion and inferior portion, but with preservation of articular cartilage in the upper quadrant. There was marked lipping of the femoral condyle, particularly in the intercondylar notch. Operation consisted of patellaplasty and removal of the medial meniscus (Fig. 10-B). The patient used crutches for one month, and returned to child nursing two months after operation. Fifteen months after operation, there was good quadriceps strength, complete extension and flexion, and the knee was "markedly improved". Straight-leg raising could be performed without a lag, but her quadriceps strength was not sufficient to allow her to go over the stairs normally, largely because she had not cooperated in the prescribed exercises. The knee was stable and painless; however, it did "tire" to some degree by the end of the day.

Case 4. E. D. D., a woman, aged sixty-four, had had pain in the right knee of four years' duration; the knee gradually became more "bent and painful". The patient had had a long period of conservative treatment, consisting of diathermy, rest and exercises, and a knee support, and two months' hospitalization with heat and rest; no appreciable relief was obtained. When examined, she stood with lateral bowing of the right knee, and 15 degrees of flexion deformity. There was rather marked generalized thickening of the joint tissues, and tremendous grating and catching on extension. There was flexion deformity of 15 degrees, with further flexion to 75 degrees. This motion was painful. Roentgenograms showed extensive proliferative changes of all the bones of both knees (Fig. 11-A).

Operation on March 20, 1947, included removal of several loose bodies, patellaplasty, and removal of both menisci on the right (Fig. 11-B). While the patient was in the Hospital, it was found that she had carcinoma of the body of the uterus, and a hysterectomy was performed. After this phlebitis developed, necessitating bilateral vein ligation. These complications delayed rehabilitation of the knee. She used crutches for three months, but gradually lost motion of her right knee, in spite of careful instruction in exercises. At this time, a mild rheumatoid state was recognized, as evidenced in other joints. Six months after operation, she had only a jog of motion of the right knee, and 20 degrees of permanent flexion. Two years after operation, her knee had shown no improvement. This has been our only real failure.

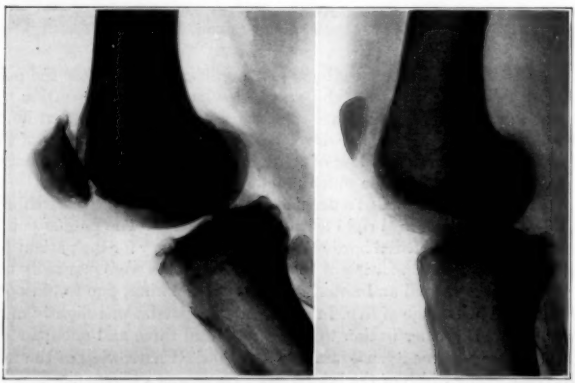


Fig. 10-A
Case 3. Before operation.

Fig. 10-B
After operation.

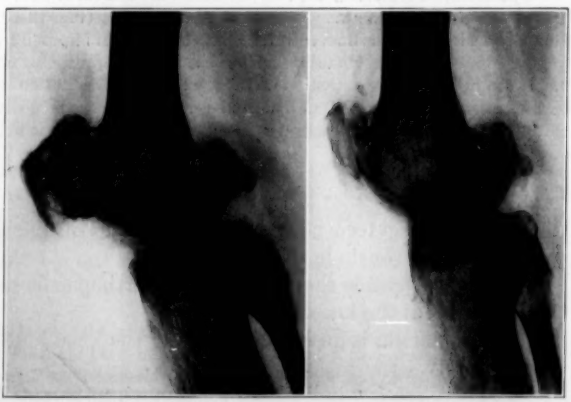


Fig. 11-A

Fig. 11-B

Fig. 11-A: Case 4. Preoperative roentgenogram, taken in November 1946.

Fig. 11-B: After operation.

Case 5. S. B., a man, aged fifty-four, was first examined on October 20, 1947. Disability of the right knee had dated from the age of five, when a diagnosis of probable tuberculosis was made. From then until the patient was twelve, the knee was more or less immobilized in various splints; at the age of twenty-five it became worse, and he was operated

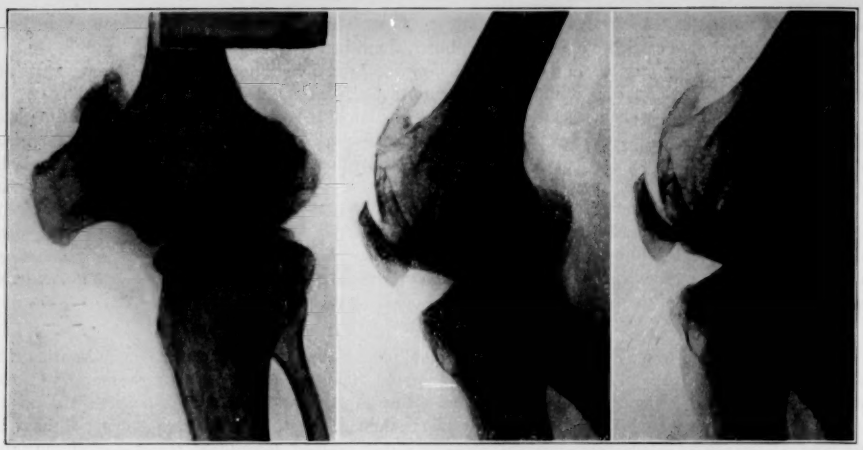


FIG. 12-A FIG. 12-B FIG. 12-C

Fig. 12-A: Case 5. Lateral roentgenogram, before operation.
Fig. 12-B: Eighteen months after operation. Fig. 12-C: Twenty-six months after operation.

upon for "removal of excess bone and cartilage". Thereafter the pain diminished, but motion did not improve. Ten years later, when he was thirty-five, a second operation was done for removal of "internal semilunar cartilage". This also gave relief for a number of years, but he continued to limp. Pain and increasing flexion deformity of the knee developed, associated with atrophy of the thigh muscles, marked thickening of the patella, and gradual loss of motion in the joint. In the patient's words, he finally had "far too little quadriceps, and much too much patella".

Examination revealed a decided limp on the right, with a lurching gait. The knee remained in 20 degrees of flexion, and was held rigid as the patient walked. The patella pointed laterally at 45 degrees, and was so prominent on the medial border that it was necessary for the patient to wear a patch on the medial side of his trousers, to prevent wearing of the cloth. Joint lines were markedly thickened, and there was extensive scarring over the medial and anterior aspects of the knee, due to old operations and cauterization of the knee, performed at the age of five. In extension, the patella was slightly movable. The knee revealed 20 degrees of fixed flexion, further flexion to 50 degrees, and three and one-quarter inches of atrophy of the right thigh. Anteroposterior roentgenograms showed marked narrowing of the medial half of the knee joint, with some increase in the width of the lateral half. There was a triangular projection of bone, medial to the tibial head. All of the bones of the right knee were markedly decalcified. In the lateral view, there was tremendous thickening and proliferation of the patella (Fig. 12-A).

Operation, on December 16, 1947, consisted in removal of the remains of the lateral and medial menisci and resection of approximately four-fifths of the patella (Fig. 12-B). No loose bodies were found. The patient's convalescence was uneventful; he has continued to improve and has no pain in the knee. He was able to give up use of a cane. He did resistance exercises vigorously for many months, and is continuing them at home. He had complete extension of the knee, and active flexion of 70 degrees. Twenty-six months after operation (Fig. 12-C) the patient had good use of his knee, walked with a very slight limp, and had a range of motion from complete extension to 70 degrees of flexion. He was able to swim and to play tennis.

CONCLUSIONS

From the eighteen cases, twelve of chondromalacia and six of hypertrophy of the patella, we may conclude that:

1. More attention should be given by orthopaedic surgeons to the patella in mechanical difficulties of the knee.

2. The patella is an essential part of the knee joint, and should not be removed indiscriminately.

3. There are few indications for removing the patella completely, chief of which is a badly comminuted fracture.

4. Articular changes in the patella may follow acute or recurrent trauma, or may be part of the general aging process of the knee joint.

5. If operation for chondromalacia of the patella becomes necessary, a conservative procedure, such as resection of the disintegrating articular cartilage, is indicated. Patellaplasty may be indicated in the severe case.

6. For the hypertrophic patella which is causing discomfort, patellaplasty, with removal of loose bodies and the menisci, is sufficient to give the best operative result.

7. With every knee arthrotomy, the patella must be examined by palpation or by direct vision.

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DISCUSSION

Dr. Harry C. Blair, Portland, Oregon: Dr. Cave has given us an excellent paper; not the least part of its value is the conservatism that it expresses. He indicates that, in surgery for chondromalacia, we should use reason and even caution. The patella normally increases the power and the ability to extend the knee. It should not be sacrificed without a definite pathological cause.

In my experience, excision of the diseased cartilage has been sufficient to alleviate symptoms. The speaker's treatment of hypertrophic patellae is interesting. I have had no experience with this operation. I wonder if there is any way to diagnose chondromalacia of the patella previous to operation. The condition is often not diagnosed and occasionally, in milder cases, spontaneous recovery occurs.

Dr. Robert I. Harris, Toronto, Canada: I rise to bear tribute to the merit of removal of the patella for the treatment of chondromalacia patellae. The subject which Dr. Cave has brought before us is one of importance and, by adequate treatment, considerable benefit can be given to patients. Since removal of the patella was first advocated by Brooke, we have passed through a variety of experiences and have concluded that, with adequate technique, removal of the patella can leave a knee in which function, in many cases, is indistinguishable from normal. The secret of the technique is to shorten the quadriceps apparatus to compensate for the gap left by removal of the patella. The simplicity of the operation, the complete freedom from pain following removal of the patella, and the adequate function after proper surgery make this procedure desirable.

The best example I can give is that of a Canadian soldier who, before the War, had his patella removed for a badly comminuted fracture. He was enlisted in spite of the absence of his patella and served for five years in an infantry regiment, until he was wounded in the opposite leg. His knee still had perfectly normal function. In Toronto, we now have experience based on over 100 cases of removal of the patella for this and similar conditions, which leads me to point out that this operation has merit and a place in the treatment of chondromalacia of the patella.

Dr. Paul B. Magnuson, Chicago, Illinois: I have enjoyed Dr. Cave's paper and think he is to be congratulated. I agree that one cannot lay down hard and fast rules for any surgical procedure, and that the decision in the individual case must be made at the operating table. I have not had occasion to remove the patella, but that does not mean that I would not do so if I thought it was indicated. In about seventy-five of these knees which we have operated upon, we have done a real house cleaning. In the last case shown by Dr. Cave, those long spurs constitute, as he said, a real derangement of the knee, and certainly it will do the knee no good to allow them to remain.

(*Continued on page 566*)

THE LUMBAR NEURAL ARCH

Roentgenographic Study of Ossification

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During the course of the roentgen examinations of forty children, in a study of ossification of the neural arch of the lumbar vertebrae, the authors were impressed by the roentgenographic appearance of the neurocentral synchondrosis in oblique views (45 degrees) of the lumbar spine, a finding of significance in both diagnostic and medicolegal evaluation.

The ossified pedicles and body do not fuse until between the third and sixth year. Prior to that time, intervening cartilage maintains their continuity. In a study of a series

Fig. 1-A

Fig. 1-B

Three vertebrae from an infant approximately one year of age were x-rayed and photographed in the same positions. The neurocentral synchondrosis is seen in the roentgenogram as a line of loss of bony continuity between the base of the pedicle and the body, and in the photograph as the dark line running in the same region. The figure demonstrates how, in the 45-degree oblique roentgenogram, the synchondrosis may be superimposed on the neural arch and appear to be a defect within it.

of postero-oblique roentgenograms of the lumbar spine in children from three to six years of age, a line was seen to be superimposed on the neural arch, which at first raised the question of a possible separation within the arch. It was found, however, that, if the outline of the neural arch were traced completely in each case, the line of diminished density could be shown to lie between the pedicle and the centrum, and, therefore, was the neurocentral synchondrosis.

Subsequent review of the whole group of roentgenograms showed that the neurocentral synchondrosis could be identified in 60 per cent. of the lumbar spines x-rayed for this study. This is not a reliable index of its true incidence in this age group, for two reasons. A slight degree of rotation of the vertebrae can obscure the synchondrosis completely by superimposing the bone of the body and the pedicle on the intervening cartilage. No attempt was made to rotate the patient at different angles in order to increase the number of positive demonstrations. Therefore, there is no reason to believe that our films show the synchondrosis more or less frequently than will any other series of routine postero-oblique films of children in this age group. In addition, three-fourths of the children in this group were five years of age or older; approximately half of them presented demonstrable synchondroses, whereas those children three and four years of age presented well defined synchondroses. Hence, the younger the children in a series, the greater will be the incidence of the synchondrosis.

FIG. 2-A

FIG. 2-B

Fig. 2-A: Postero-oblique roentgenogram of a stillborn infant at term. Note the width of the neurocentral synchondrosis and its distribution through the sacrum and thoracic vertebrae.

Fig. 2-B: Antero-oblique roentgenogram of vertebrae from skeleton of infant approximately one year of age. The neurocentral synchondrosis is narrowed as compared to Fig. 2-A.

FIG. 2-C

FIG. 2-D

FIG. 2-E

Fig. 2-C: Postero-oblique roentgenogram of a child three years of age. The synchondrosis remains quite prominent. By tracing the arch in its entirety or by comparison with Fig. 1-A, it can be seen that the region of lack of bone continuity is at the junction of the body and the pedicle, not in the neural arch.
Fig. 2-D: Postero-oblique roentgenogram of a child five years of age. The line at the synchondrosis is less distinct and persists in fewer vertebrae.
Fig. 2-E: Postero-oblique roentgenogram of a six-year-old child, showing only a vestige of the neurocentral synchondrosis. The line is visible only in the fifth lumbar vertebra, very faintly, where fusion remains incomplete at the superior (arrow) and inferior margins of the junction of the body and pedicle.

The sacrum presented the synchondrosis approximately as frequently as the lower lumbar vertebrae, but the frequency of demonstration decreased steadily in each segment superior to the fifth lumbar vertebra. Thus in all cases with only one synchondrosis, it was present in the fifth lumbar vertebra; in those cases which showed more than one, the synchondroses were in the fifth lumbar as well as in the fourth lumbar, the sacrum, or other lumbar segments.

To elucidate further the appearance of the neurocentral synchondrosis, roentgenograms and photographs were taken of three vertebrae from a skeleton of an infant approximately one year old, in the 45-degree oblique view (Figs. 1-A and 1-B). Roentgenograms were also taken of laboratory specimens, consisting of a full-term foetus and the skeletonized vertebrae of a child approximately one year old, for comparison with the clinical roentgenograms of children three, five, and six years of age (Figs. 2-A to 2-E). The neurocentral synchondrosis is seen to disappear gradually as fusion progresses.

The recognition of such normal variations as the lines seen roentgenographically between the os trigonum and the talus, and between the epiphysis and the base of the fifth metatarsal, in children, avoids the error of their being diagnosed as fracture. So, too, the establishment of the nature of this apparent "defect" in the neural arch should dispel any misconcept that might occur to the examiner of a child whose back had been the object of trauma or the source of pain.

ABSORPTION OF PROTRUDED DISC TISSUE

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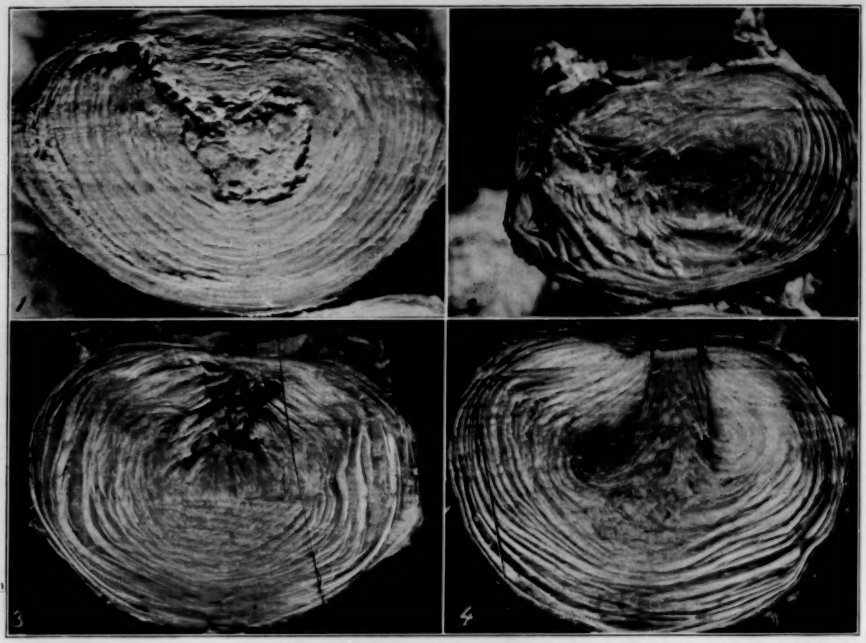
It is well known that intervertebral-disc tissue disappears. A lumbar disc may decrease in volume from about 15 cubic centimeters to 1 cubic centimeter. The intercellular substance of the nucleus pulposus diminishes, and a small amount of the disc tissue may escape as disc prolapse. However, this explains only a minor part of the process of diminution.

A study of the structure of intervertebral discs, based on 160 postmortem examinations[7, 8] shows that radial rupture often occurs in the early stages of disc degeneration, followed by a prolapse of disc tissue through the fissure. The herniating masses consist of nucleus pulposus as well as annulus fibrosus, and may include the internal portions as well as those fibers which outline the radial rupture. All stages from radial rupture with beginning loss of tissue to almost complete disappearance of the nucleus and annulus are seen. In the intermediate stages, the bundles of the annulus appear cut off at the periphery of the disc (Figs. 1 to 4). It is obvious that the disc tissue is "digested" and absorbed as it reaches the disc surface.

In order to explain the absorption process, a microscopic study was performed by one of us (G. H.) on three ruptured discs, found among the anatomical specimens, and on material removed at operation in forty cases of prolapse of the disc. The results were as follows:

Closely connected with the necrotic and degenerated parts of the disc tissue, loose



FIGS. 1, 2, 3, and 4

Photographs of four discs with dorsolateral and posterior ruptures, demonstrating the cut-off appearance of the bundles of the annulus. Ingrown vessels are seen in Figs. 1, 2, and 3. External apposition of connective tissue is present in Figs. 1 and 2. Fig. 1 represents an early stage in which nuclear tissue remains in the disc center.

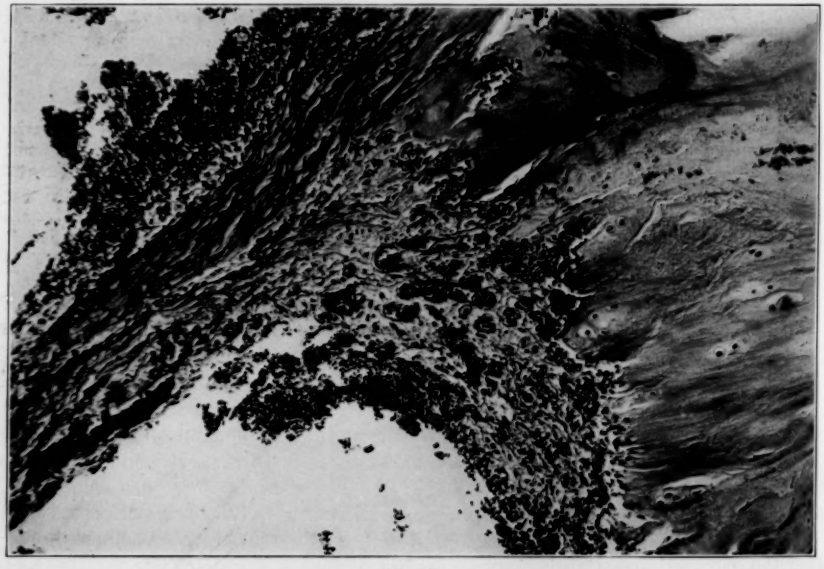


FIG. 5

Photomicrograph (× 40) of the "cut-off" bundles of the annulus, seen grossly in Fig. 3. At the left is the invading granulation tissue which "digests" the annulus.

FIG. 6
(× 333)

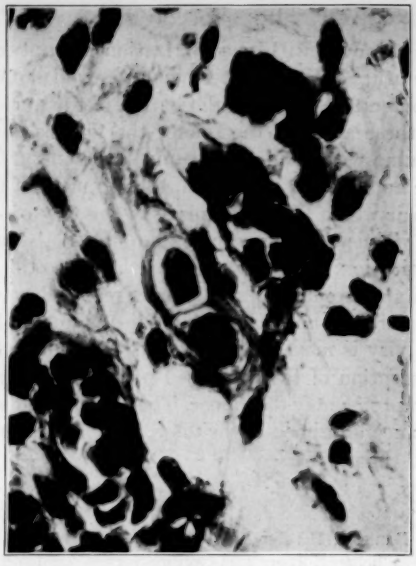


FIG. 7
(× 500)

Figs. 6, 7, and 8: Progressive magnifications (× 333, × 500, and × 900, respectively) of a disc prolapse during organization, demonstrating loose granulation tissue rich in blood vessels, with small cartilage fragments scattered throughout the granulation tissue. (Staining: Weigert hematoxylin and von Gieson's method.)

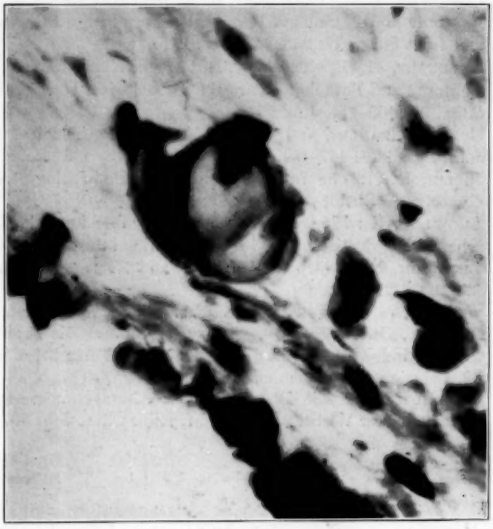


FIG. 8
(× 900)

granulation tissue was sometimes seen (Fig. 5), with many thin-walled vessels of varying caliber, usually small and distended with red blood cells. In the granulation tissue, fibroblasts, sparse lymphocytes, and larger cells rich in cytoplasm—probably phagocytic elements—were present. Remnants of disc tissue with clear chondroid structure were found. The boundary between the disc tissue and the granulation tissue was usually sharp, as if the protruding tissue had been cut off; sometimes it was ragged. No foreign-body reaction with giant cells was observed. In the neighborhood of the degenerated disc tissue, the granulations were looser and more voluminous. Farther from the disc remnants, the granulation tissue seemed shrunken and condensed, and an increasing number of collagen fibers were found.

In nineteen of the forty cases of disc prolapse, biopsy of the disc tissue showed the changes described.

DISCUSSION

Fibrosis with vascularization of ruptured discs is well known from reports in the literature [1–6, 9–11]. In specimens removed at operation, Eckert and Decker found fibroblastic proliferation and vascularization of the nucleus pulposus in about 25 per cent. According to these authors, the role of the fibrosis and vascularization is probably "the result of trauma with resultant healing". Coventry, Ghormley, and Kernohan [3] stated: "Tears in the annulus are seen often, though most of them are old, as evidenced by the amount of repair which has taken place in the way of invasion of blood vessels and fibrous tissue."

Thus the ingrowth of granulation tissue has been looked upon as a sign of repair or restitution. However, seen in relation to the macroscopic picture of the disc degeneration in its different stages, it is more reasonable to consider the cellular and vascular ingrowth as a sign of absorption. The disc is not replaced by invading tissue; it is "eaten". The activity is most pronounced in the region of the prolapsed portion of the disc,—that is, absorption of the prolapsed portion takes place. As a result, the prolapse as well as its symptoms may disappear. The cellular and vascular reaction also leads to some fibrosis in the neighborhood of the discs, the longitudinal ligament, the dura, the roots, the ganglion, and the nerves.

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PARTIAL SCAPULECTOMY FOR SNAPPING OF THE SCAPULA

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The condition of scapular snapping was apparently first investigated in 1867 by Boinet. Later, sporadic articles appeared in English, French, and German. In 1933, Milch and Burman reviewed the literature, added a number of cases, and called particular attention to the fact that an abnormal forward curvature of the medial angle of the scapula might be the cause of the symptoms. Recently, attention has again been directed to "the rattling shoulder blade" [4] and to the existence of a scapulothoracic syndrome. Although the subject has been somewhat neglected, scapular snapping is far from rare.

In most instances, palliative treatment is advised, and the likelihood of radical cure appears to be seldom discussed. Indeed, even thoroughly competent orthopaedic surgeons have expressed surprise at the possibility and consequences of surgical therapy. For this reason a brief recapitulation of the subject would seem justified.

The noise, which has come to be called scapular snapping or grating, is of a varied nature. It may resemble the fine grating characteristic of muscular noises; it may be coarse and even thumping in effect, resembling somewhat the muffled sound made when a stick is drawn across a picket fence. It may present itself as a single snap, a series of intermittent low thuds, or a continuous grating sound. Generally speaking, it may be defined as a tactile-acoustic phenomenon, occurring as a consequence of some anomalous condition existing between the thoracic wall and the undersurface of the scapula. Mauclaire [6] divided the sounds into three main classes:

1. *Froissement:* a gentle friction sound which must be considered physiological.
2. *Frottement:* a somewhat louder sound.
3. *Craquement:* a loud snapping noise which is invariably of pathological import.

Experience definitely confirms Mauclaire's opinion with respect to the loud snapping, but the significance of the gentle grating sounds has been largely overlooked. By far the majority of cases fall into the second category, and patients in this group complain not only of disturbing sounds, but also of disabling pain. These patients are described as neurotic; they are referred for consultation to the internist or to the neurologist; they are given baking and massage; but seldom, if ever, are they sent to an orthopaedic surgeon for specific therapy.

In general, scapular snapping has been caused by changes in the bone structure, in the muscles, or in the bursae. The changes in the bone structure may occur either in the ribs or in the scapula. Although exostosis and angulation of the ribs have been observed, pathological conditions of the scapula constitute by far the more common causes of scapular snapping. Among these are: (a) abnormal curvation of the superior angle of the scapula; (b) the tubercle of Luschka; and (c) tumors, especially osteochondromata, of the scapula.

Milch and Burman reported cases in which excessive forward curvature of the superior angle of the scapula was the whole cause of the snapping. An oblique roentgenogram of the shoulder revealed forward angulation, and resection of this area of the scapula resulted in prompt cure of the condition.

Somewhat similar, in that excessive anterior projection of the superior angle resulted from the presence of the small osteochondroma at the superior angle, are the cases of so-called Luschka's tubercle. Grünfeld stated that this small bony or fibrocartilaginous nodule, situated on the anterior aspect of the superior angle of the scapula, was first described by Luschka. In 1872, it was also reported by Gruber, who found it in seven of a

series of twenty cadavera. Some authors consider the tubercle the probable cause of the crepitation; others have disputed its causal relationship. In Case 1, resection of the tubercle undoubtedly cured the condition.

CASE 1. T. G., a policeman, aged thirty-one, was first seen in February 1949. His initial symptoms had appeared in 1943, when he struck his left shoulder against a water cooler. Shortly thereafter he had noted a slight stiffness in his shoulder, and about one week later, stiffness in his neck, for which he was given gentle massage. The symptoms persisted intermittently for about one year before the patient noted grating in the left scapular region. After that time there was constant crepitation, with occasional pain during motion of the left shoulder.

The upper extremity was completely normal except that, with motion, a peculiar succession of sounds were heard, resembling the muffled noise made when a stick is drawn across a picket fence. This sound could be eliminated by elevating the scapula away from the thoracic cage. Roentgenograms of the left shoulder (Fig. 1-A), taken in an oblique direction, showed a definite thickening and bulbous appearance of the superomedial angle of the scapula.

Operation was performed with local anaesthesia on February 28, 1949, an oblique muscle-splitting incision being used. The posterior-superior angle of the scapula was found to be definitely thickened. When the patient was asked to move the shoulder, it could be seen that the noise was in truth caused by the thumping of the superior angle of the scapula across the upper ribs. When the scapula was held away from the chest wall, the sound disappeared.

FIG. 1-A

Case 1. T. G. Oblique roentgenographic view of left scapula. Note bulbous thickening of superior angle,—so-called tubercle of Luschka.

Resection of the superior angle of the scapula resulted in immediate disappearance of the sound, even when the scapula was permitted to move normally upon the chest wall.

The specimen (Fig. 1-B) showed a bulbous thickening, just at the superior angle of the scapula. This was covered by cartilage, precisely in the manner of the more common type of osteochondroma, and undoubtedly represented the thickening described as the tubercle of Luschka.

Convalescence was uneventful and the patient was permitted to leave the Hospital on the fourth postoperative day. Since that time he has had no symptoms, and has been able to engage in his normal work.

While the tubercle of Luschka has been described as a separate entity, it may perhaps be classified in the larger group of osteochondromata of the scap-

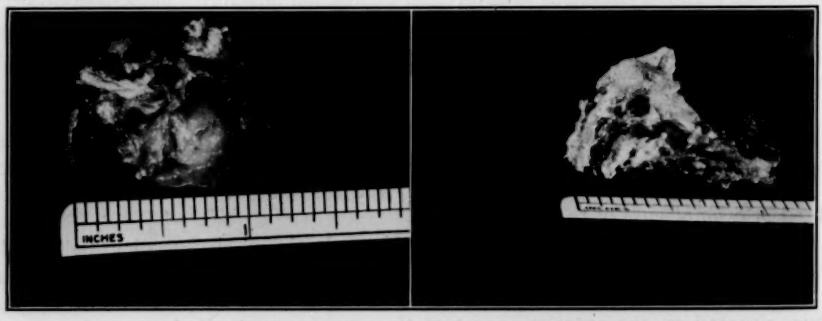

FIG. 1-B

Resected portion of superior angle of scapula with tubercle of Luschka.

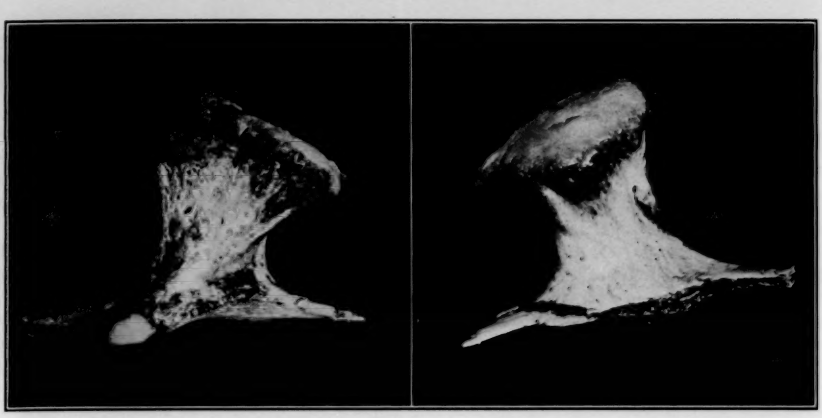

FIG. 2

Case 2. G. R. Resected portion of scapula with mushroom-shaped osteochondroma of ventral surface. Its contour and the cartilaginous apex are characteristic of this lesion.

ula. Although these constitute the most common tumors of the scapula, they must be considered as rare. In all records of the Hospital for Joint Diseases, only about fifteen cases of scapular tumor, benign or malignant, could be found. Scapular osteochondromata may be either single or multiple. They are usually benign, but may be primarily malignant or may undergo malignant degeneration. Only those which develop on the anterior surface of the scapula give rise to snapping. Because of their development between the scapula and the body wall, they present a characteristic mushroom-shaped appearance. The base and the cap are definitely broader in diameter than the shaft of the tumor. The flattened cap usually consists of cartilage which seems to be very much like metaphyseal cartilage. During the period of active epiphyseal growth of the long bones, the cap of the tumor continues growing; but as soon as the long bones cease their growth, the osteochondroma also stops growing. Removal of the osteochondroma with the adjacent area of the scapula leads to permanent cure, as illustrated in the following case:

CASE 2. G. R., aged thirteen years and six months, was first seen in June 1941, three weeks after friends had noted a prominence of the right scapula and had remarked that her shoulder was "humped". The girl had experienced no pain. The scapula was markedly winged. When the child moved her shoulder, the characteristic thumping could be felt as the scapula moved across the ribs. The cause of this was manifest. At the level of the spinous process, the vertebral border of the scapula was held away from the thorax by a large sessile bony mass, attached to the anterior surface of the scapula. This was shown by roentgenogram to be a typical osteochondroma.

On June 16, 1941, with the girl under general anaesthesia, the typical mushroom-shaped osteochondroma (Fig. 2) was excised with the scapular base to which it was attached.

Convalescence was uneventful and the patient left the Hospital on the fifth day after operation. There have been no symptoms since. The pathologist reported a typical benign osteochondroma.

A rather unusual cause of scapular snapping is presented by the following case:

CASE 3. D. R., a girl, aged three, was admitted to the Hospital on February 2, 1949. She was suffering from a number of malformations, including webbing of the toes, triple phalanges of the right thumb, stenosing tendovaginitis of the left thumb, and an apparent winging of the left scapula.

Although the child did not complain of pain, her mother had observed grating during motion of the shoulder. This was localized to the region of the superior angle of the left scapula and appeared to be associated with a mass, which was increasing in size with the growth of the child.

The child kept her head tilted to the left; bending or twisting to the right was restricted. Both scapulae were a trifle higher than normal. On the left side there was a suggestion of winging, but otherwise the configuration of each appeared normal. Scapular motion was not restricted, but on the left side a coarse, grating crepitation could be heard and felt on motion. This crepitation was localized to the region of the posterior-superior angle of the scapula. Palpation of this area revealed a large bony mass, extending obliquely upward

and medialward from the angle of the scapula toward the vertebral column. It appeared to be attached in the mid-line, but was clearly not fixed to the scapula.

Anteroposterior roentgenograms of the cervical spine were reported as showing: "Underdevelopment of the first cervical vertebra; partial fusion of the second and third cervical vertebrae with complete fusion of their laminae and spinous processes; compression of the body of the fourth cervical. The sixth and seventh cervical vertebrae are moderately underdeveloped. The laminae appear to be fused and their spinous processes form one large homogeneous mass, projecting backward and to the left in the soft tissues of the cervical region. In oblique view [Fig. 3] it can be seen that this process projects toward, but is not continuous with, the superior angle of the scapula."

A diagnosis of "omovertebral bone" was made and its removal was advised. On June 20, 1949, with the child under general anaesthesia, the bony mass was exposed. It was found to be attached to the scapula only by dense connective tissue, and was a continuation of the large spinous process of the fifth cervical vertebra, with less secure attachments to the spinous processes of the sixth and seventh cervical vertebrae. The pathological specimen was reported as being "an irregular oval-shaped mass of bone, measuring 2.5 centimeters in length, 1.5 centimeters in width, 4 millimeters in thickness. One edge is covered by cartilage, representing a growing plate area."

The child made an uneventful recovery and had complete elimination of the scapular snapping.

Although not so spectacular as the group of bone tumors, probably the most common cause of scapular snapping is to be found in changes which occur in the surrounding muscles. Except for those instances in which a true bursa can be demonstrated, this second group includes most of the cases involving soft-tissue changes. In all likelihood, these changes are of the nature of an interstitial myofibrosis. Depending upon the group of muscles involved, the snapping may be localized at any point on the periphery of the scapula. The area of scapula to be resected will be determined by the localization of the sound.

In the following case, the snapping was localized at the superior angle and resection produced prompt relief, both of the noise and the pain.

Case 4. P. M., a woman, aged twenty, was first seen in May 1949, with the complaint of pain and a "creaking sensation" in the region of the left scapula. She had consulted many physicians, but had been informed that nothing could be done to remedy the condition.

The noise of which the patient complained was clearly audible during any motion of the left scapula.

Fig. 3

Case 3. D. R. "Omovertebral bone" attached to cervical vertebrae, in contact with the superior angle of the left scapula.

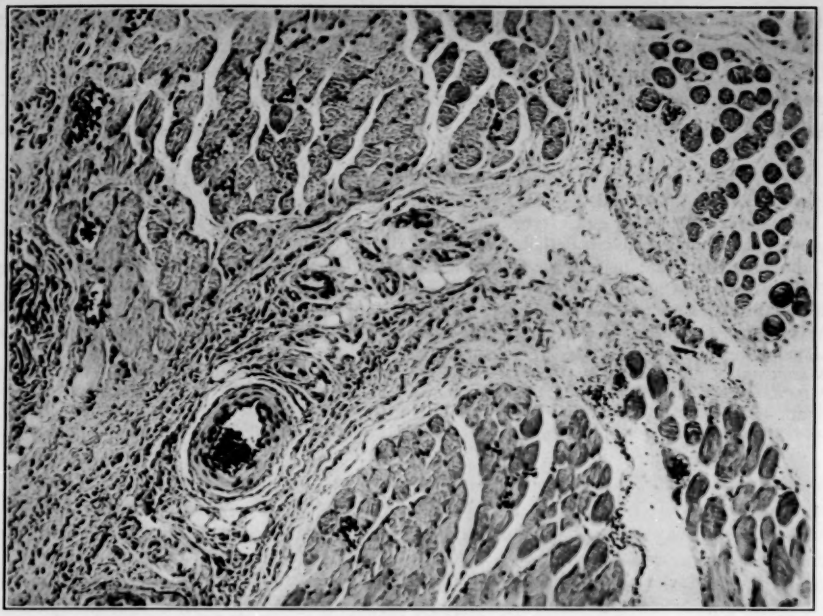

FIG. 4

Case 4. P. M. "Interfascicular fibrosis", associated with snapping of the scapula, was cured by resection of the superior angle of the scapula.

Through the flat of the hand, the origin of the noise could be localized to the region of the superior medial angle. When the patient's left hand was placed on her right shoulder, or when the vertebral border of the scapula was lifted away from the chest wall, the noise disappeared instantly.

Roentgenograms of the shoulder and scapula were taken from every angle. No bone abnormality or even excessive forward curvature of the scapula could be demonstrated. Nevertheless, it was felt that the crepitus was due to an abnormal rubbing together of the tissue between the scapula and the chest wall.

The medial angle of the scapula was removed on May 14, 1949, general anaesthesia being used. The superomedial angle of the scapula, extending over to but not including the suprascapular notch, was resected. The thoracic cage was explored carefully. No exostosis was found on the ribs, but in the subscapularis, directly beneath the resected portion of the scapula, there was marked thickening and a bursal formation was excised. The pathologist, J. Ehrlich, reported:

"Section reveals portions of voluntary muscle with associated fibrous and fat tissues from region of scapula. In several areas interfascicular fibrosis is present. The proliferating connective tissue separates and surrounds muscle bundles and in one or two places invades the periphery of these bundles. The scar tissue is composed of thin, delicate compact wavy fibers which have a taut appearance, in contrast to the normal loose collagen bundles present elsewhere. Occasional lymphocytes are scattered through these areas of scarring. In one region the muscle is completely uninvolved. Striations appear within normal limits. Blood vessels do not show significant changes. Fat tissue is also essentially unaltered. There is some traumatic (surgical) hemorrhage near the periphery of the specimen. In some places the process extends into the major septa. Diagnosis: Portions of voluntary muscle showing areas of interfascicular fibrosis and chronic inflammation. Fragments of bone from scapula" (Fig. 4).

The convalescence was uneventful and within a week the patient was discharged. There was no limitation of motion in any direction, and all scapular noise had vanished.

SUMMARY

Scapular snapping may vary in character and etiology. Although local conditions, such as the tubercle of Luschka or an osteochondroma, may long antedate the onset of symptoms, trauma would seem to play some part in precipitating the patient's com-

plaints of discomfort or of disability. The sound originates as the result of contact between parts of the scapula and the chest wall. Elevation of the scapula from the chest wall leads to immediate cessation of the sound. In all instances, the localization of the noise determines the site of resection. Simple removal of portions of the scapula will result in prompt and permanent cure.

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DISCUSSION

The Patella

(*Continued from page 553*)

After débridement of the knee, we get the patient out of bed in eight days, and this is a job for the surgeon himself. He should lift the patient, put him on his feet, and start him walking, keeping step with him. The patient should stand straight, without bending the hip or the knee and without looking at the floor; he will soon learn that there is no pain if the weight is borne squarely on the knee, without the use of crutches or canes. If the surgeon will walk with the patient every day for eight or ten days, not turning this over to an assistant or intern, the patient will regain his confidence and do much better. The physical therapist may be the world's best, but it is the surgeon in whom the patient has confidence, and it is the surgeon who must make him work until the quadriceps has regained its power.

I have not found it necessary to remove a patella in any of these cases, and do not believe that it is indicated if there is sufficient cartilage to form a cushion over the condyles and under the patella. It is surprising how much can be removed and still leave good tracks on which the patella can glide.

Dr. Edwin F. Cave (closing): From the discussion which has taken place, one can easily see that there is considerable difference of opinion as to what should be done with patients who have chondromalacia of the patella, as well as with those suffering from hypertrophy of the patella. I appreciate very much the remarks of Dr. Blair, Dr. Harris, and Dr. Magnuson, and I was particularly interested in what Dr. Harris said about excision of the patella for chondromalacia. His series is, indeed, an impressive one.

Most of the cases in our series were treated in the Army, and we were hesitant to excise the patella of a soldier, because we were afraid we could not restore the men to any form of duty. As a matter of fact, a very high percentage of the patients upon whom we did conservative operative procedures returned to some form of duty, and it shall be my policy in the future to carry out such a procedure until we are able to determine that excision of the patella does not do harm. I suspect that some of the patellae Dr. Harris has excised may partially re-form in the extensor apparatus. Perhaps if these patients are x-rayed within a few years, they may show an area of calcification approximately the size we have remaining after a patellaplasty. That remains to be seen.

I am sure that Dr. Magnuson has struck the keynote about the great necessity of careful and prolonged efforts to rehabilitate these elderly people, no matter what type of reconstructive operation is done on the knee. It has not been our practice to excise hypertrophic spurs from the femoral or tibial condyles if these spurs are covered with reasonably good articular cartilage.

I hope our paper has stimulated interest in the patella, which, I am sure, has been grossly neglected in the past. Accumulation of a large series of such cases will add to our knowledge of this most important bone.

STUDY OF FRACTURE HEALING BY MEANS OF RADIO-ACTIVE TRACERS

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One of the numerous problems connected with healing of fractures is that of whether the processes involved are purely local—that is, limited to the fracture itself and the tissues immediately about it—or whether the whole skeletal system is affected.

Roche and Mourgue examined the phosphorus and nitrogen content of different bones of rats and pigeons at various periods after a fracture. They found that the phosphorus-nitrogen ratio decreased during the first twenty days after the fracturing and then increased; the ratio reached normal values about forty to fifty days after the fracturing, finally decreasing slightly again. These changes in chemical composition occurred not only in the fractured bone, diaphysis as well as epiphysis, but the authors found similar, although less pronounced, changes in the intact bones. They concluded that the entire skeletal system acts as a unit, and that local influences can be traced throughout the skeleton.

In the present investigation, an attempt has been made to follow the changes in a fractured bone, as well as the possible effect of the fracture on the intact part of the skeleton, radiophosphorus and radiocalcium being used as tracers.

As is well known, Chievitz and Hevesy [3, 4] showed with radio-active phosphorus that a continuous exchange takes place in living bones. Hevesy, Holst, and Krogh found the exchange to be greatest in those bones which contain most organic tissue. According to Manly and his associates and to Hevesy, Levi, and Rebbe, it is possible to differentiate between superficial layers, where the exchange is rapid, and inner parts, where the process is slower. More recently, Marshak and Byron investigated the uptake of radiophosphorus and radiostrontium by the injured bone. They found that the activity measured with a Geiger-Müller counter at the place of injury, as compared with the activity measured over the homologous intact bone, was highest twelve to fifteen days after the injury. Copp and Greenberg obtained similar results by using radiostrontium in the study of fracture healing under the influence of vitamins A and D. Armstrong and Barnum recently investigated the uptake of radiophosphorus (P^{32}) and of radiocalcium (Ca^{45}) in different parts of the skeletal system of rats. They found the bone marrow to have the highest specific activity, the specific activity of the epiphysis being less and that of the diaphysis still lower.

EXPERIMENTAL FINDINGS

The animals used in the authors' experiments weighed between 150 and 200 grams. They were living under the same conditions as regards diet, light, and temperature. The beta-radiation emitted by the radiophosphorus present in the rat corresponded to about 5 to 10 × 43 r during the five days of radiation. Marinelli and Kenney applied 3,000 r to obtain a significant effect on the phosphorus metabolism of the bone tissue. Recently, observations by Lawrence and his associates have shown that whole-body irradiations in doses below 200 r produced no changes whatsoever in the blood of rats, and that only questionable changes were produced by irradiations of between 200 and 500 r.

Four series of experiments were carried out, as follows:

1. One series of experiments was carried out on nine rats, divided into three groups, one animal in each group being used as a control (Table 1).

The experimental animals had their right femora broken manually, ether anaesthesia

* Professor E. Dahl-Iversen, Director.
** Professor Niels Bohr, Ph.D., Director.

TABLE I

RESULTS IN FIRST SERIES OF EXPERIMENTS *

Animal No.	Bones	Total Activity in Counts per Minute (Right Humerus = 100 **)	Total Activity of Intact Bones	Activity per 100 Milligrams	Excess Activity per 100 Milligrams in Right as Compared to Left Bone (*Per cent.*)
		Group I			
1	Right femur	234		1058	+35
	Left femur	192		784	
	Right humerus	100	397	803	−4
	Left humerus	105		839	
2	Right femur	255		927	+40
	Left femur	196		660	
	Right humerus	92	378	708	+6
	Left humerus	90		669	
3	Right femur	159		588	−1
(Control)	Left femur	163		596	
	Right humerus	95	349	710	+5
	Left humerus	91		673	
		Group II			
4	Right femur	185		569	+34
	Left femur	162		423	
	Right humerus	100	347	538	+3
	Left humerus	85		522	
5	Right femur	346		1760	+75
	Left femur	204		1005	
	Right humerus	95	402	979	−6
	Left humerus	103		1038	
6	Right femur	256		972	+4
(Control)	Left femur	250		932	
	Right humerus	136	518	1025	0
	Left humerus	132		1028	
		Group III			
7	Right femur	431		927	+76
	Left femur	211		527	
	Right humerus	100	415	541	−5
	Left humerus	104		568	
8	Right femur	422		1080	+71
	Left femur	216		631	
	Right humerus	103	424	578	−10
	Left humerus	105		639	
9	Right femur	125		455	+2
(Control)	Left femur	121		445	
	Right humerus	87	304	506	+3
	Left humerus	96		491	

* The animals in Group I received 1 microcurie of P^{32} one week after fracture of the right femur; those in Group II, a similar dose two weeks after fracture; and those in Group III, the same amount three weeks after fracture.

** The figures in this column are given as percentages of the figure for the right humerus.

TABLE II

RESULTS IN SECOND SERIES OF EXPERIMENTS *

No. of Animals	Bones	Average Activity per Milligram	Excess Activity per Milligram in Right as Compared with Left Bone (*Per cent.*)
	Group I		
5 (Experimental)	Right femur, epiphysis	19.4	+39
	Left femur, epiphysis	14.0	
	Right femur, diaphysis *b*	26.2	+58
	Left femur, diaphysis *b*	16.6	
	Right femur, diaphysis *a*	20.3	+171
	Left femur, diaphysis *a*	7.5	
	Right tibia, epiphysis	21.4	+43
	Left tibia, epiphysis	15.0	
	Right tibia, diaphysis	12.3	−2.4
	Left tibia, diaphysis	12.6	
2 (Control)	Right femur, epiphysis	15.5	−0.7
	Left femur, epiphysis	15.6	
	Right femur, diaphysis *b*	20.1	+5.8
	Left femur, diaphysis *b*	19.0	
	Right femur, diaphysis *a*	8.3	0
	Left femur, diaphysis *a*	8.3	
	Right tibia, epiphysis	16.6	+1.8
	Left tibia, epiphysis	16.3	
	Right tibia, diaphysis	13.3	+0.8
	Left tibia, diaphysis	13.2	
	Group II		
5 (Experimental)	Right femur, epiphysis	14.1	+23
	Left femur, epiphysis	11.5	
	Right femur, diaphysis *b*	17.3	+41
	Left femur, diaphysis *b*	12.3	
	Right femur, diaphysis *a*	15.8	+182
	Left femur, diaphysis *a*	5.6	
	Right tibia, epiphysis	14.3	+17
	Left tibia, epiphysis	12.2	
	Right tibia, diaphysis	10.0	+11
	Left tibia, diaphysis	9.0	
2 (Control)	Right femur, epiphysis	9.5	−6.9
	Left femur, epiphysis	10.2	
	Right femur, diaphysis *b*	12.3	−1.6
	Left femur, diaphysis *b*	12.5	
	Right femur, diaphysis *a*	5.4	+1.9
	Left femur, diaphysis *a*	5.3	
	Right tibia, epiphysis	9.8	−1.0
	Left tibia, epiphysis	9.9	
	Right tibia, diaphysis	9.4	−6.0
	Left tibia, diaphysis	10.0	

* The animals in Group I received 2 microcuries of P^{32} two weeks after fracture of the right femur; those in Group II, the same dose four weeks after fracture.

Diaphysis *a* refers to the fracture plus 5 millimeters of adjacent bone, distal and proximal.

Diaphysis *b* refers to the rest of the diaphysis (including the metaphysis).

being used. At different intervals after the fracturing, each animal received an injection of radio-active phosphorus; they were killed five days later. The interval of five days between administration of P^{32} and sacrifice of the animals was chosen in order to make sure that the specific activity of blood, lymph, and muscles was so low that contamination or adherence to the bone would not affect the measurements. After the animal had been sacrificed, a roentgenogram of the broken bone was usually taken. Subsequently, the femora and humeri were cleaned. The fracture site was then examined macroscopically. The bones were weighed and ashed at 800 degrees centigrade for two hours (white ashing). The ash was ground and placed *in toto* in aluminum dishes. The samples weighed from 50 to 200 milligrams; the two to be compared were of almost equal weight. The radiophosphorus was measured with a Geiger-Müller counter[1].

2. A second series of experiments were carried out with fourteen rats divided into two groups, each group comprising five experimental animals and two controls (Table II). In the first group, the animals received P^{32} intraperitoneally fourteen days after the fracturing; in the second group, twenty-eight days after the fracturing. Only femora and tibiae were used in this experiment. After ashing at 800 degrees centigrade, each bone was divided in the following way: The epiphysis was first separated from the diaphysis; this could easily be done at the epiphyseal line. The diaphysis of each femur was cut into two parts, one containing the fracture itself and 5 millimeters of adjacent bone in the distal as well as the proximal direction. This was possible in most cases, as the fracture was in the middle of the femur; in a few cases, where the fracture was just above the knee, only the diaphysis proximal to the epiphyseal line was included in this portion. The rest of the diaphysis, including the metaphysis, was measured collectively. The left femur was treated the same as the right femur. The tibiae were divided only into epiphysis and diaphysis.

3. Experiments were performed on nine rats divided into three groups, one control animal being in each group (Table III). The bones from one experimental animal were boiled in alkalized ethylene glycol before the ashing; the bones of the other experimental animal were ashed directly. In this experiment the P^{32} injection was given before the bones were fractured.

4. Experiments were also carried out with radio-active calcium (Table IV). In view of the soft beta-rays emitted from Ca^{45}, self-absorption in the samples to be measured must be taken into consideration. On account of this, the difference in weight between samples to be compared must not exceed 1 milligram. For samples around 50 milligrams, a variation of ± 1 milligram will reduce the variation in counts to less than 2 per cent.

These experiments, comprising twenty-four rats with fractured femora, show only a fraction of the total experimental data which include measurements on more than 100 rats and some guinea pigs. All the fractures gave similar results.

RESULTS

As shown in Table I, the P^{32} content per milligram of ash of the fractured bone is considerably higher than that of the homologous bone or of the bone of intact animals. While, one week after the fracture, the fractured bone takes up 30 per cent. more P^{32} than does the homologous intact bone, the corresponding difference after the lapse of two weeks is about 50 per cent., and as much as 75 per cent. three weeks after the fracturing. The difference between the P^{32} content per milligram of ash from homologous intact bones and control animals never exceeds 10 per cent., the mean deviation being 5 per cent.

In Table II are listed the results of the experiment in which the bones were separated into different parts after being ashed. The increase in activity was not localized to the fracture site itself and its nearest surroundings, but a distinct effect was found in both the epiphysis and the adjoining diaphysis. Even the proximal epiphysis of the right tibia was influenced by the fracture, whereas the diaphyseal part of the right tibia showed no difference from the left.

TABLE III

INJECTION OF RADIOPHOSPHORUS PRIOR TO FRACTURE OF BONE *

Animal No.	Bones	Total Activity in Counts per Minute (Right Humerus = 100 **)	Total Activity of Intact Bones	Activity per 100 Milligrams	Excess Activity per 100 Milligrams in Right as Compared to Left Bone (*Per cent.*)
		Group I			
1	Right femur	167		392	+12
	Left femur	159		350	
	Right humerus	100	358	464	+2
	Left humerus	99		456	
2	Right femur	255		617	+8
	Left femur	235		571	
	Right humerus	142	521	712	−5
	Left humerus	144		746	
3	Right femur	180		390	−3
(Control)	Left femur	185		401	
	Right humerus	106	392	493	−3
	Left humerus	101		509	
		Group II			
4	Right femur	183		489	+23
	Left femur	166		398	
	Right humerus	100	365	542	+5
	Left humerus	99		514	
5	Right femur	163		505	+9
	Left femur	151		464	
	Right humerus	102	357	605	0
	Left humerus	104		603	
6	Right femur	174		476	0
(Control)	Left femur	172		478	
	Right humerus	99	375	566	−3
	Left humerus	104		583	
		Group III			
7	Right femur	183		557	+9
	Left femur	168		511	
	Right humerus	100	366	575	+1
	Left humerus	98		571	
8	Right femur	205		408	+13
	Left femur	173		361	
	Right humerus	106	386	479	0
	Left humerus	107		480	
9	Right femur	195		458	−4
(Control)	Left femur	204		476	
	Right humerus	98	398	521	+4
	Left humerus	96		502	

* All of the animals in this experiment received 4 microcuries of P^{32} five days before fracture of the right femur. In Group I the animals were sacrificed one week after fracture; in Group II, two weeks after fracture; and in Group III, three weeks after fracture.

** The figures in this column are given as percentages of the figure for the right humerus.

TABLE IV

EXPERIMENTS WITH RADIO-ACTIVE CALCIUM *

Animal No.	Bones	Total Activity in Counts per Minute (Calculated from Measurement of 50 Milligrams)	Total Activity of Intact Bones	Activity per 50 Milligrams	Excess Activity per 50 Milligrams in Right as Compared with Left Bone (*Per cent.*)
		Group I			
1	Right femur	808		323	+119
	Left femur	354		147	
	Right humerus	163		146	+2
	Left humerus	160	1047	143	
	Right tibia	154		96	−20
	Left tibia	216		120	
2	Right femur	720		289	+112
	Left femur	345		136	
	Right humerus	167		139	+1
	Left humerus	170	1078	137	
	Right tibia	174		95	−15
	Left tibia	222		112	
3	Right femur	377		138	−4
(Control)	Left femur	403		144	
	Right humerus	186		144	+7
	Left humerus	175	1264	134	
	Right tibia	249		120	+3
	Left tibia	251		117	
		Group II			
4	Right femur	727		211	+115
	Left femur	336		98	
	Right humerus	170		105	−3
	Left humerus	177	1108	108	
	Right tibia	220		96	+7
	Left tibia	205		90	
5	Right femur	556		307	+72
	Left femur	352		178	
	Right humerus	186		191	+6
	Left humerus	175	1155	180	
	Right tibia	223		156	+14
	Left tibia	219		137	
6	Right femur	477		357	−1
(Control)	Left femur	465		361	
	Right humerus	188		336	−2
	Left humerus	192	1453	344	
	Right tibia	319		313	+4
	Left tibia	289		301	

* The animals of Group I received 1 microcurie of Ca^{45} one week after fracture of the right femur; those of Group II, two weeks after fracture.

Before it was learned that the epiphysis could be separated from the diaphysis merely by ashing, an experiment was carried out in which the bones were boiled in alkalinized glycol for two hours to dissolve the organic tissue. The experiment gave a similar result to that seen in Table II; but, as the glycol dissolves a small part of the inorganic substance, the

objection was raised that the glycol might have induced some activity to be transferred from the site of fracture to the epiphysis. No objection of this kind, however, can be made against the revised experiment.

The results of experiments in which the radiophosphorus was injected prior to the fracture of the bone are shown in Table III. The fractured right femur took up only slightly more P^{32}, or in some cases the same amount, as the intact left bone. In some of these experiments, the organic constituents were removed by boiling with alkalinized glycol for two hours. The glycol was then transferred to glass cuvettes [13] and the activity was measured. The sample in which the fractured right femur had been boiled showed a higher activity than that in which the left femur had been boiled.

The last experiment, with the application of radiocalcium, gave the same results as those obtained with radiophosphorus. One week after fracture of the right femur (Table IV), the right tibia had taken up less Ca^{45} than had the left tibia. A similar effect was observed in experiments with P^{32}, not described here.

DISCUSSION

The difference in activity between the fractured bone and the homologous intact bone may be caused either by building up of new tissue or, at least in part, by an increased exchange of phosphorus and calcium, respectively, between the bone and the surrounding plasma and lymph. During healing of the fracture new tissue is built up, as can be seen from the cartilaginous tissue found during dissection of the fractured leg and from the roentgenograms of the fracture taken after three weeks. Moreover, an enhanced interchange between plasma and lymph phosphorus and bone phosphorus is confirmed by the following observations:

1. The increase in activity of the fractured bone is not localized to the region of the fracture, but appears also in the metaphyseal and the epiphyseal parts of the bone, even though the latter were distinctly separated from the fracture site. A distinct effect is seen also in the proximal tibial epiphysis.

2. Further support is found in the third experiment. P^{32} was administered five days prior to the fracturing. According to Manly and his co-workers, the specific activity of the blood (that is, of the plasma) will in the course of five or six days after injection of P^{32} reach equilibrium with the superficial layers of the bones. From then on, the activity of the bone will increase only slightly. If an increased exchange begins at this time, it will not produce any change in the activity of the bone. A building up of new bone, however, should appear as an increasing activity of the fracture. Thus, the effect of exchange is eliminated, and the results presented in Table III support the assumption that the difference in P^{32} uptake, as shown in Tables I, II, and IV, is due mainly to an increase in exchange and not to formation of new tissue.

Marshak and Byron and Copp and Greenberg measured the activity of the fracture after administration of radiophosphorus by placing a Geiger-Müller counter on the fracture (or injury). They observed the highest activity after the lapse of twelve to fifteen days, while in the authors' experiments the activity was still not decreasing after the lapse of four weeks. The divergence of the results obtained may be ascribed to the experimental procedure. While the workers just mentioned [5, 11] measured the outer layers of bone at the place of injury (the beta-rays from P^{32} do not penetrate more than a few millimeters into bone tissue), where new deposits of bone substance were going on, we measured the inner layers and the neighboring layers as well.

In order to compare the above-mentioned results with the work of Roche and Mourgue, the total activity of the intact bones of the experimental and the control animals within each group must be compared. As the animals of each group were given almost the same amount of P^{32}, the bones, if they react alike, should show the same activity within the individual variation of resorption and excretion. The values given in

the tables as the sum of the activity of the different bones of each animal, minus the activity of the fractured bone, show no support for the assumption that all the bones in an animal with an induced fracture take part in the processes of healing. However, it is possible that the method used in this investigation is not sufficiently sensitive to demonstrate a small effect of the type mentioned.

Work is in progress to study these problems, as well as other related problems, more thoroughly.

SUMMARY

Experiments with radiophosphorus and radiocalcium, administered to rats at different periods during the healing of fractures, show increased activity of the bone ash from the fractured bone as compared with the ash from homologous intact bone of the same animal.

Further investigations indicate that this effect is due mostly to an increased exchange of phosphorus and calcium between the plasma and the mineral substance of the bone. Measurements of the separated epiphysis indicate that this process involves the whole bone and the proximal epiphysis of the tibia as well.

Applying these results to the work of Roche and Mourgue, we are unable to confirm that the processes taking part in the healing of a fracture can also be found in the skeleton as a whole.

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UNUSUAL FRACTURE-SUBLUXATIONS OF THE SHOULDER JOINT *

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An infrequently recognized type of subluxation of the shoulder joint, associated with fractures of the surgical neck, has been observed at St. Luke's Hospital. In such a subluxation, the head of the humerus teeters on the lower margin of the glenoid and is usually displaced somewhat anteriorly as well as distally. The subluxation is seen in association with fracture of the surgical neck, or with combined fractures of the surgical neck and greater tuberosity, simulating fracture of the anatomical neck. It occurs both in the adduction type of fracture of the surgical neck which results from a fall on the lateral aspect of the elbow, and also in the abduction type in which the shaft is angulated outward from a fall on the medial aspect of the elbow or forearm. This fracture-subluxation should be differentiated from a true fracture-dislocation of the shoulder. It does not require manipulative reduction or open operation to replace the head in the socket.

From January 1947 to July 1948, the authors collected six such fracture-subluxations. A search of the literature revealed but scant mention of this unusual subluxation prior to that time. Cotton, in 1921, reported nine cases, eight of which were in women of heavy build. He did not state what percentage of fractured shoulders these nine cases represented. Dehne, in 1939, mentioned that such subluxations did occur, but likewise expressed no percentage of incidence. In several fracture textbooks [4, 5], reproductions of roentgenograms showed the subluxation in fractures of the surgical neck, but no mention was made of its being a specific entity. In August 1948, after the authors had begun this study, Fairbank reported twelve cases found in a series of 115 fractures, an incidence of slightly under 10 per cent. The authors now have treated eighteen cases, six of these, from the Fracture Service at St. Luke's Hospital, representing an incidence of 20 per cent.

H. C., a woman, sixty-one years old, sustained a fracture of the surgical neck with comminution of the greater tuberosity (Fig. 1-A). On the date of fracture there was partial subluxation of the head. A sling and Stimson dressing were applied to reduce the subluxation. Later she had active motion and gravity exercises to gain mobility and muscle tone of the shoulder. Nine weeks from the date of fracture the subluxation had been largely reduced (Fig. 1-B), but there was still some downward displacement of the head in relation to the glenoid socket. Twelve months after fracture (Fig. 1-C), there was perfect replacement of the humeral head into the glenoid socket. The tuberosity fragment healed with a slight prominence, so that there is limitation of overhead motion. The function of the shoulder is but 50 per cent. of normal.

This case is shown because of the marked subluxation noted in the original roentgenogram. She is the only patient in this series who had failed to regain full motion at the time of follow-up examination, as a result of conservative care.

S. J., a woman, sixty-seven years old, sustained a fracture of the surgical neck without gross displacement of the greater tuberosity (Fig. 2-A). There is no reason to believe that the rotator cuff was torn. On the day of fracture the head was not materially subluxated from the glenoid, but the roentgenogram taken one day later (Fig. 2-B) showed subluxation. Previously this subluxation was believed to have been due either to beginning relaxation of the muscles of the shoulder joint, with release of spasm, or to some deficiency of muscle tone, so that the head became subluxated. Clinically, a depression could be seen and felt between the overhanging acromion and the head of the humerus, suggesting subluxation. The lateral roentgenograms on the date of fracture showed the head to be very slightly displaced anteriorly, as well as inferiorly (Fig. 2-C). The view taken one day later (Fig. 2-D) showed definite anterior and inferior displacement of the head from the glenoid. (This subluxation, in the authors' experience, has always occurred anteriorly as well as inferiorly, and not posteriorly.)

Three weeks after the fracture (Fig. 2-E), there was callus formation and the humeral head was still in essentially the same downward and forward position of subluxation as that seen one day following the

* Read at The American College of Surgeons Fracture Day, New York, N. Y., February 12, 1949.

FIG. 1-A FIG. 1-B FIG. 1-C

Fig. 1-A: H. C. (St. Luke's Hospital No. X-255194). Fracture of surgical neck and comminution of greater tuberosity with subluxation. Appearance on day of injury.

Fig. 1-B: Nine weeks later, subluxation was incompletely reduced. Fracture fragments had united.

Fig. 1-C: Twelve months after fracture, showing complete replacement. Interposed tuberosity fragment limited overhead motion.

fracture. At the end of eight weeks (Fig. 2-F), however, the head was replaced in the socket. The patient regained normal function and had a stable socket, as proved by traction roentgenograms taken after one year.

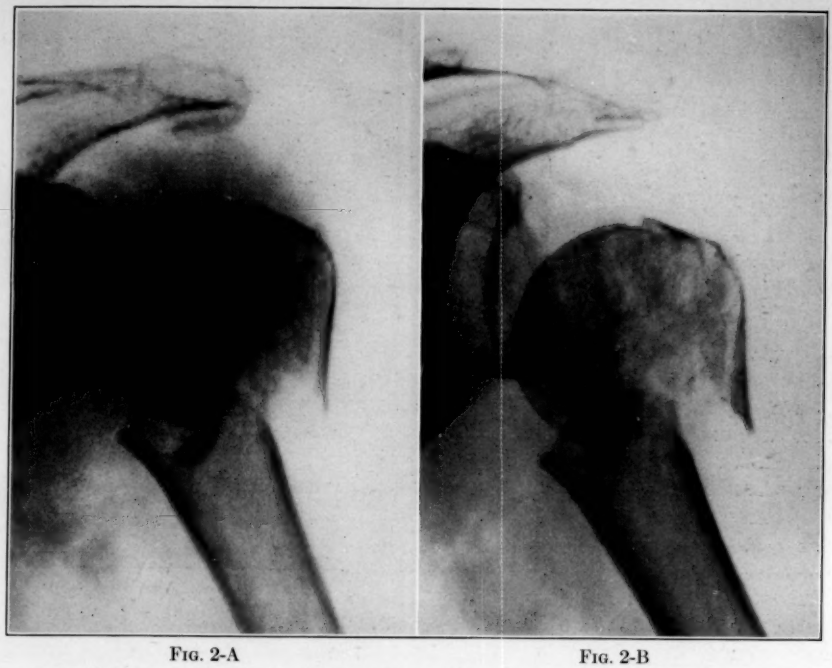

FIG. 2-A FIG. 2-B

Fig. 2-A: S. J. (St. Luke's No. 259277). Fractured surgical neck on date of injury. Head had minimal subluxation.

Fig. 2-B: Subluxation present one day later.

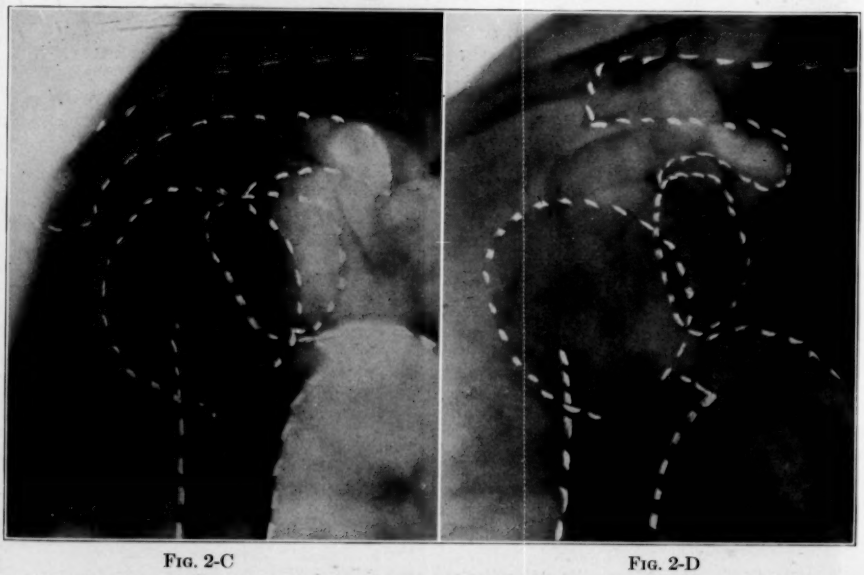

FIG. 2-C FIG. 2-D

Fig. 2-C: Lateral view with patient standing, showing minimal antero-inferior subluxation on day of fracture.

Fig. 2-D: Lateral view one day after fracture, showing definite antero-inferior subluxation.

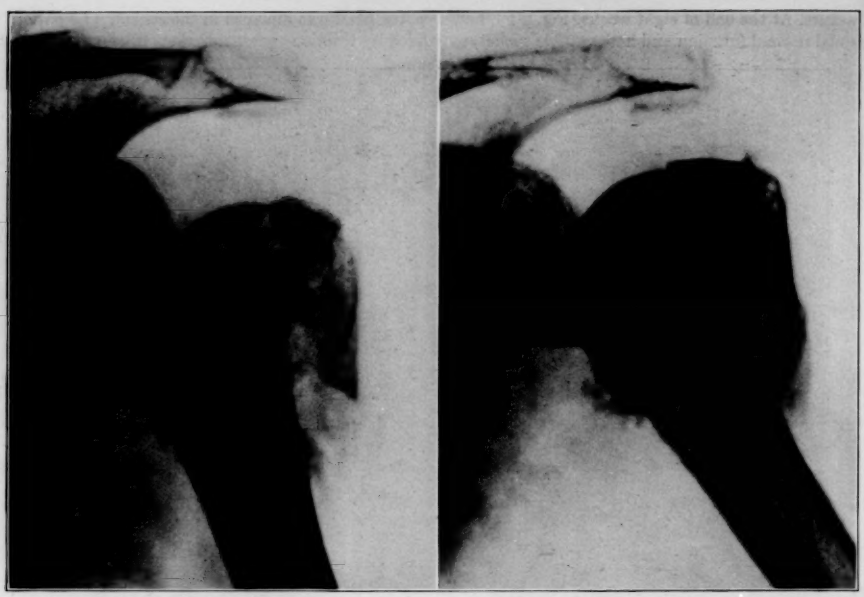

FIG. 2-E FIG. 2-F

Fig. 2-E: Three weeks after fracture, head was still subluxated.
Fig. 2-F: Complete replacement, eight weeks after fracture.

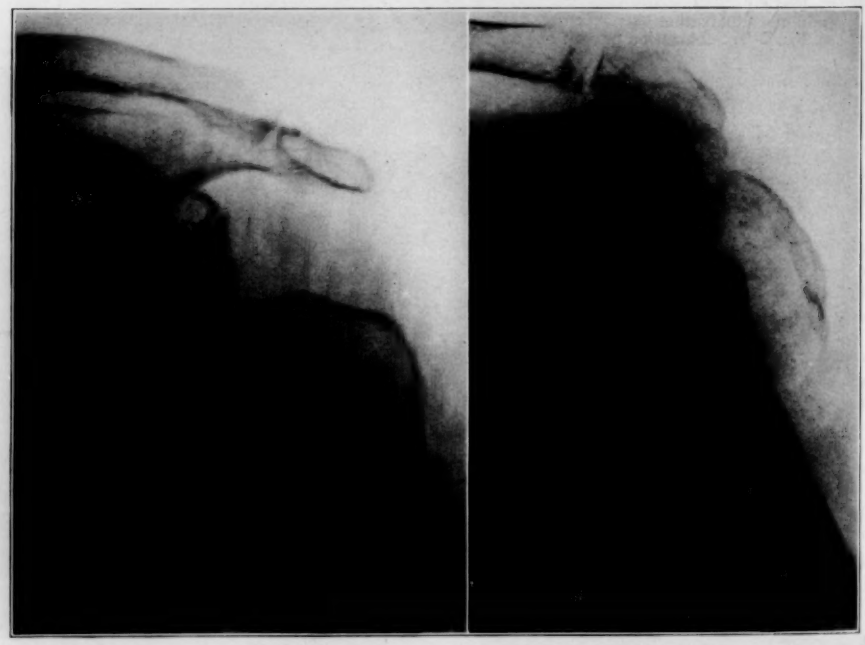

FIG. 3-A FIG. 3-B

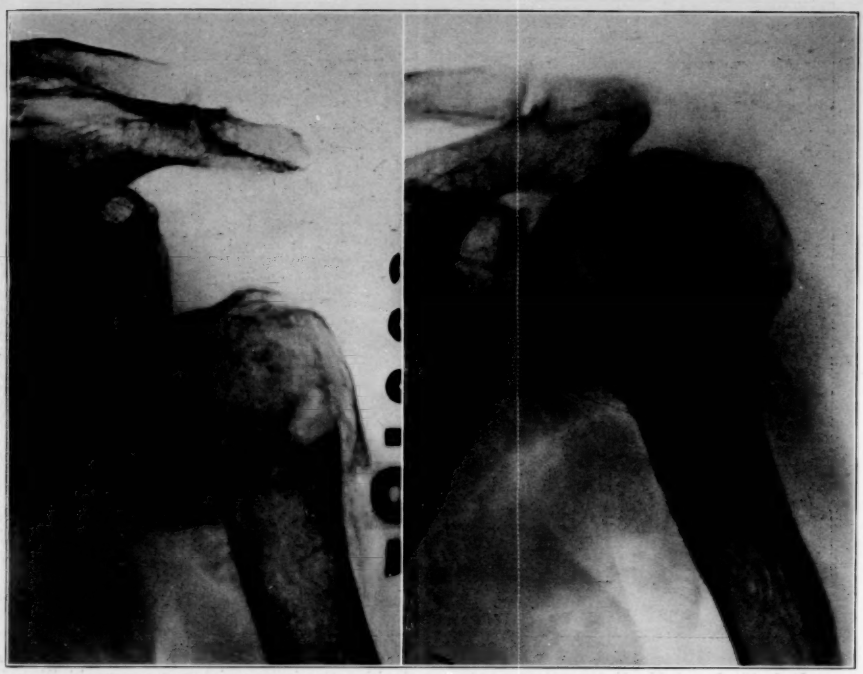

FIG. 3-C FIG. 3-D

Fig 3-A: M. C. (St. Luke's No. X-261359). Subluxation present on day of fracture.
Fig. 3-B: One day after fracture, subluxation had been reduced by sling.
Fig. 3-C: Five weeks after fracture, head was resubluxated.
Fig. 3-D: Six months after fracture, there was normal relation of head to glenoid socket.

This case has shown us that the subluxation may not be noticed in the roentgenogram taken the first day of fracture, but may be visible subsequently, due to some change that occurs in the shoulder. The reason for this will be shown later. In none of these patients has paralysis of the deltoid been noted.

In the case of M. C., a woman, seventy-two years old, subluxation was seen on the day of fracture (Fig. 3-A). One day later (Fig. 3-B) the subluxation had been reduced. The patient was treated by a sling and was allowed to sit up and to walk about the ward. The sling had been applied snugly in order to reduce the subluxation, since it was thought that the original fracture was impacted and that the fragments were not displaced by this rather snug upward push against the elbow.

The two roentgenograms show that the subluxation may be reduced by a firmly fitting sling. However, the upper fragment was tilted by the application of the sling. The clinical depression palpable between the acromion and the head of the humerus disappeared as the sling was applied snugly, so that the shoulder no longer felt or looked subluxated. Five weeks after fracture (Fig. 3-C) the head had again become definitely subluxated from the socket, as a result of active motion and gravity exercises. The sling, of course, was not always kept taut and snug during that time. The patient had been discharged from the Hospital and had regulated the snugness herself. Five weeks after fracture the depression was still palpable and visible at the outer point of the shoulder. In the roentgenogram taken six months after injury (Fig. 3-D), the subluxation had entirely reduced itself. The general increase in tone of the muscle was thought to be responsible for this. The final function of this shoulder at the end of one year was excellent; the joint was perfectly stable in both the traction and upward-push roentgenograms.

Mechanism of the Subluxation

Using a fish scale, the authors experimentally tried a pull of fifty pounds on a normal shoulder; the shoulder could not be subluxated by continuous or strong traction. Fair-

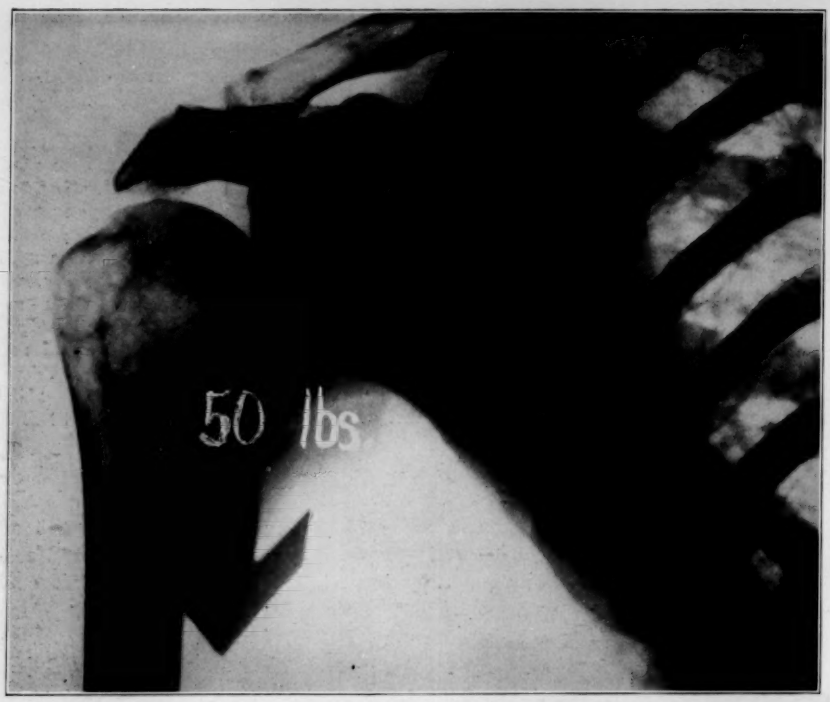

FIG. 4

H. L. (St. Luke's No. X-269831). Shows failure of subluxation in man, eighty-one years old. With the patient under anaesthesia, fifty pounds of traction was applied for twenty minutes.

bank, in his paper, showed a roentgenogram of subluxation produced in a shoulder while the subject was under anaesthesia. The authors were unable to produce such subluxation by a pull of fifty pounds in an anaesthetized subject. Figure 4 shows a man, eighty-one years old, who had fifty pounds' pull for twenty minutes, anaesthesia being used. This roentgenogram shows a general downward stretching of the structures of the shoulder joint, but not subluxation. There is no buckling inward of the soft tissues of the rotator cuff to replace the negative pressure made by the pull, as demonstrated by Fairbank in one of his illustrations. In films taken on the date of fracture, the authors found a slight swelling or fullness of the tissues, resulting from the trauma. The capsule has never been markedly distended, as if from the presence of blood or effusion into the joint; Fairbank showed that an effusion of blood under pressure would leak out of the joint by way of the groove of the long biceps tendon.

Fairbank stated that a general relaxation of all the muscles of the shoulder girdle, without paralysis, was responsible for this phenomenon or subluxation. By cadaver dissection, he found that no one muscle held the head in the socket. As each hardened, formalinized muscle was severed, the head could be distracted farther and farther from the glenoid center. Fairbank made no mention of the capsule in these dissections. The authors found, however, that typical subluxation could be produced in the cadaver simply by cutting the capsule at the anterior and inferior glenoid rim. To gain exposure to do this, it was necessary to detach the coracoid process and retract distally the bone with its muscle origin. The other muscles were left intact. From this experimental work, the authors believe that these subluxations are due to tears of the capsule, a minor stage of the classical dislocation of the humeral head with fracture of the surgical neck. The anterior displacement seen in the lateral roentgenograms (Fig. 2-D) tends to confirm this.

We do not believe that some strange relaxation of the muscles of the shoulder girdle causes it, as concluded by Fairbank. In three later cases in this series, the shoulder was explored to determine if this capsular tear was present. A large rent in the capsule was found anteriorly in two of them, as suspected; in the third patient the capsule was com-

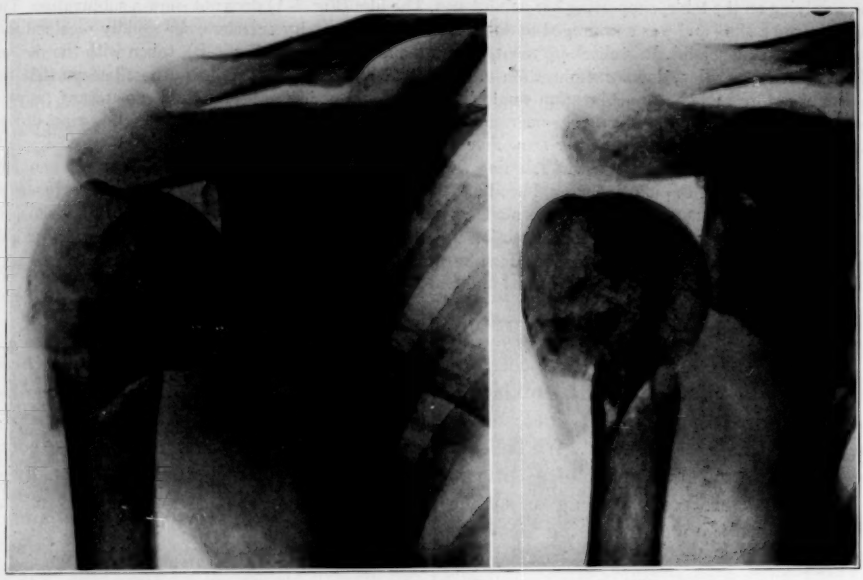

FIG. 5-A FIG. 5-B

Fig. 5-A: S. K. (St. Luke's No. X-258167). On the day of fracture, with the patient lying on table supporting painful arm, no subluxation was demonstrated.
Fig. 5-B: Roentgenogram one month later, with the patient standing, showed subluxation.

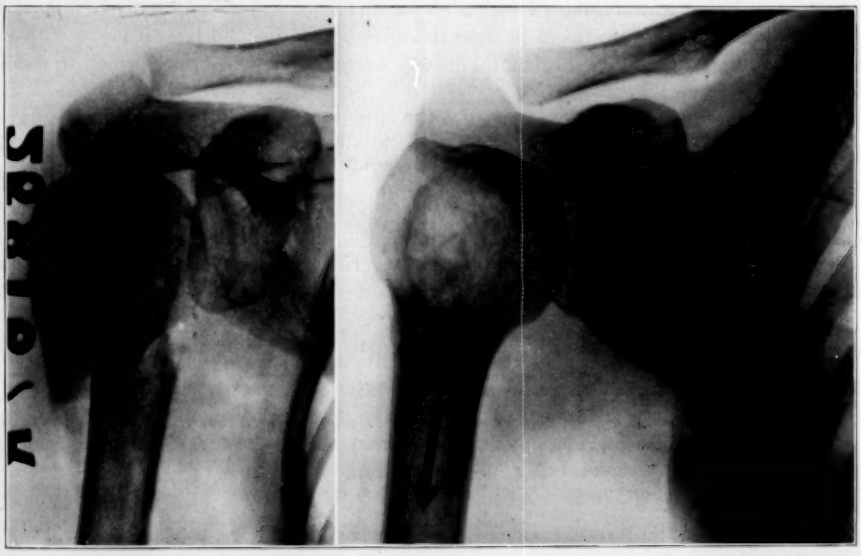

FIG. 5-C FIG. 5-D

Fig. 5-C: Five weeks later, head was replaced in socket.
Fig. 5-D: One year and eight months after the fracture, reduction had been maintained.

pletely torn away from its posterior and inferior humeral attachments. In spite of this posterior tear, the shoulder was subluxated inferiorly and anteriorly.

Importance of Roentgenograms Taken with the Patient Standing

S. K., a woman, who was thirty-five years old on the date of fracture, had roentgenograms taken while she was lying on the table, supporting her painful arm. The film (Fig. 5-A) does not show a subluxation. The patient wore a sling and was encouraged to do active horizontal gravity exercises; she rapidly regained motion of the shoulder joint. In a check-up roentgenogram one month later (Fig. 5-B), taken with the patient in the standing position, definite subluxation of the shoulder joint is visible. The authors believe that the capsule was torn and that a subluxation would have been evident in the beginning, if downward traction had been exerted at the time the roentgenograms were taken or if the patient had been standing erect during the procedure, without supporting her arm. Five weeks after the subluxation was demonstrated, a roentgenogram taken while the woman was standing (Fig. 5-C) showed that the structures about the shoulder had tightened enough to pull the humeral head back in the socket. This replacement in the socket persisted in the subsequent roentgenograms, as shown one year and eight months after injury (Fig. 5-D). Follow-up films with vigorous traction and countertraction upon the arm demonstrate that the shoulder was stable and did not become subluxated upward or downward. The patient regained full function. It is the authors' belief that the tear in the capsule had healed and remained secure.

Aseptic Necrosis

In slightly over half of these cases there was comminution, with the humeral head present as a separate fragment, simulating the vascular problem of a fracture of the anatomical neck. In spite of this fact, conservative treatment has not resulted in aseptic necrosis of the head fragment. We believe, however, that surgery is indicated in selected cases, because of the danger of aseptic necrosis. Primary surgery is indicated in those cases with severe compounding or such gross displacement that the upper end of the shaft juts into the axilla, causing nerve pressure.

SUMMARY

Fracture-subluxations are an entity and should be so classified. They represent the primary stage of a fracture-dislocation of the humeral head with partial tearing of the capsule.

There has been an incidence of 20 per cent. of subluxation among cases of fracture of the surgical neck at St. Luke's Hospital. This incidence will undoubtedly be higher as routine roentgenograms are taken in both the anteroposterior and lateral views with the patient standing, especially if horizontal gravity exercises have been performed to relieve muscle spasm.

Early surgery directed at correction of the subluxation is not indicated, but surgery may be necessary to correct the position of the fracture fragments. The hanging cast has no place in the treatment of this complication of a fractured surgical neck. Sling support with early horizontal gravity exercises will, in the majority of the cases, produce a satisfactory result. In none of our cases was the subluxation permanent. In all, the subluxation corrected itself within six weeks of the date of fracture. All the shoulders were stable at follow-up examination, when the roentgenograms were taken with vigorous traction and with an upward push. If permanent instability or subluxation should be present, it may be necessary to do some type of capsular repair, such as the Bankart procedure.

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SURGICAL RECONSTRUCTION OF THE PARALYTIC SHOULDER BY MULTIPLE MUSCLE TRANSPLANTATIONS †

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Except for the experience of Mayer and Haas in transplanting the trapezius, muscle transplantation about the shoulder has been practised only sporadically in this country. This lack of popularity is accounted for by the many failures which have resulted, probably from a poor selection of cases and too much optimism in the presence of severely paralyzed muscles. Extensive weakness of even a single muscle may result in ataxia of the whole shoulder region. The greater the number of muscles that are involved, the more profound is the ataxia and the less likely it is that the condition will be remedied by muscle transplantation. This principle was recognized by Haas, who noted poor results from trapezius transplantation when extensive paralysis was present about the shoulder.

The basis for the multiple muscle transplantations reported in this paper is the fundamental work of Ober [16], who many years ago reported transplanting the long head of the triceps and the short head of the biceps to the acromion region. Ober [17, 18] also devised and practised other muscle transplantations in this region, noteworthy being shifts of the origin of the deltoid and transplantation of the origin of the pectoralis major. Moore [14, 15] and L'Episcopo described muscle transplantations for residual disability following "birth" paralysis. Other transplantations, applicable in some cases, are the pectoralis major reinforcement of the biceps brachii [2] and use of the pectoralis for winged scapula [4]. Steindler and Tubby have described operative techniques.

The literature on reconstructive surgery in poliomyelitis abounds with references to "isolated deltoid paralysis" and to "paralysis at the shoulder", usually signifying ineffective abduction of the arm. Actually, few cases of isolated total paralysis of the deltoid exist. In many cases of paralysis of the trapezius and serratus anterior due to poliomyelitis, the arm and shoulder girdle are ineffective, although the deltoid remains normal. Haas and Mayer have recognized these facts in a general way by stating that the results of their trapezius transplantations were better in cases with little or no disability in the "accessory" shoulder muscles. Riedel summarized the subject of muscle transplantations in this region as recorded in Germany prior to 1928.

In the normal person, both for abduction and forward flexion, a constant relationship of 2 degrees of motion at the scapulohumeral joint to 1 degree of lateral rotation of the scapula occurs after 30 degrees of abduction has been reached [8, 11]. For forward flexion, this fixed ratio does not become established until 60 degrees of abduction has been reached. Normal relations between the scapula and humerus are upset in patients with residual paralysis from poliomyelitis, as illustrated later in this paper.

Assuming total paralysis of at least the anterior and middle portions of the deltoid, experience with the five cases to be reported here suggests that:

1. Scapular fixation or relative immobility can be secured either by muscle control, by muscle contracture, or through axioscapular fascial transplants [1, 10]. In the cases of scapular fixation by muscle contracture or fascial bands, the loss of the last 30 to 60 degrees of abduction must follow. The minimum muscle combination for effective scapular control includes fair to good function in both trapezius and serratus anterior. The rhomboids do not appear to be so essential, especially since the medial scapular border is well controlled by only a trace of function in the rhomboids, if serratus function is good.

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† Presented as a Scientific Exhibit at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 22 to 27, 1949.

2. There should be fair to good function in the rotator-cuff muscles, especially the supraspinatus.

3. Effective external rotation of the humerus must be either present or obtainable by transplantation of the latissimus dorsi and the teres major over the lateral aspect of the humerus, so that they will function as external rotators, or by transplantation of a portion or all of the pectoralis major to the postero-inferior portion of the greater humeral tuberosity. Normal function of the pectoralis major, subscapularis, teres major and teres minor, latissimus dorsi, and the lower trapezius and rhomboids does not appear to be essential.

The trapezius was not transplanted in any of these cases.

The surgical incisions used are shown in Figures 1-A and 1-B. All the possibilities of transplantation of the pectoralis major and the latissimus dorsi were not exhausted in the three cases reported in which one or both of these muscles were utilized. Cadaver dissection revealed that both muscles could be widely mobilized.

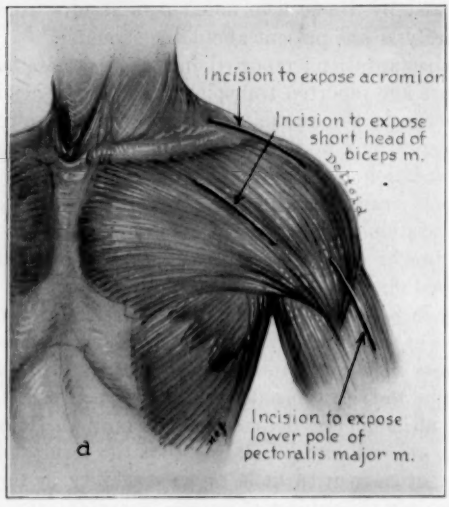
Incision to expose acromion
Incision to expose short head of biceps m.
Deltoid
Incision to expose lower pole of pectoralis major m.
a

FIG. 1-A

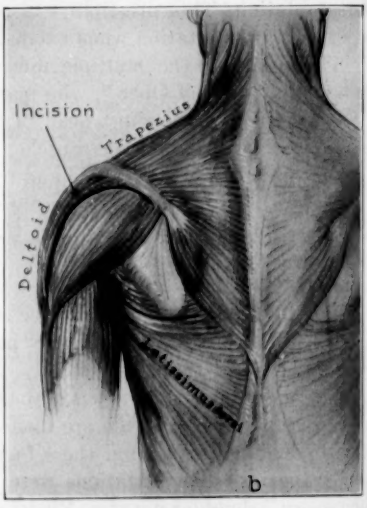

FIG. 1-B

The surgical incisions used for transplantation of muscles in the cases reported.

ANATOMICAL STUDIES OF MOTOR NERVES *

Thirty-three cadavera were examined to determine the lengths of the mobile portion of the motor nerves to the pectoralis major, the latissimus dorsi, the deltoid, and the long head of the triceps. The infraclavicular portions of the lateral and medial anterior thoracic nerves varied in their peripheral branching. The lateral anterior thoracic nerve in some of the specimens was a single trunk; in others, two or even three trunks. The single-trunk variant usually branched 1 or 2 centimeters after piercing the costocoracoid membrane. The length of these nerves, including the single trunk, varied from 4 to 6 centimeters. The single trunk was 1 to 2.5 centimeters long. The medial anterior thoracic nerves, two or three in number, emerged for the most part below the pectoralis minor. Their length varied from 8 to 14 centimeters distal to the clavicular level.

The thoracodorsal nerve supplying the latissimus dorsi was a long, mobile, free-lying trunk, 12 to 18 centimeters in length, as measured from the point of divergence from the posterior cords of the plexus to its usual entry into the junction of the middle and distal thirds of the muscle. This muscle and its nerves and vessels could be displaced

* Work done by the author in the Department of Anatomy, College of Medicine, University of Cincinnati.

Diagrammatic representation of the preoperative muscle strength in five cases.

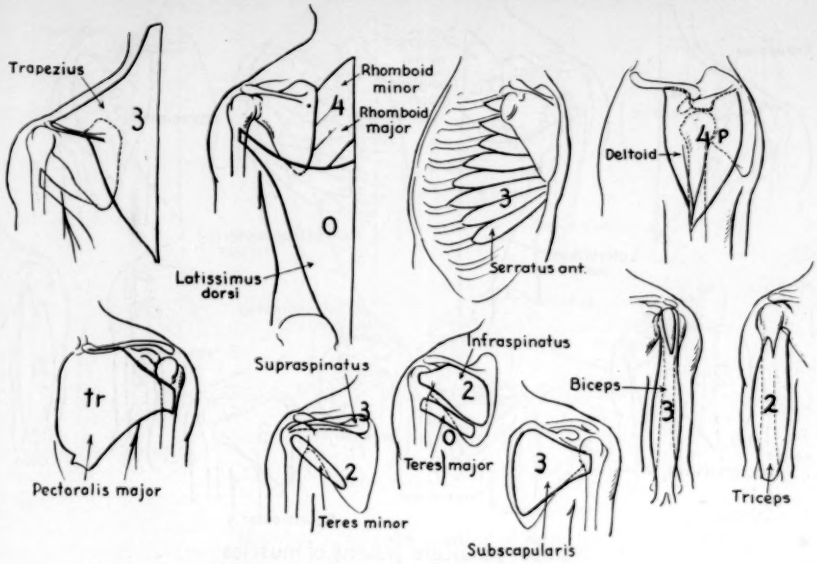

FIG. 2-A

Case 1

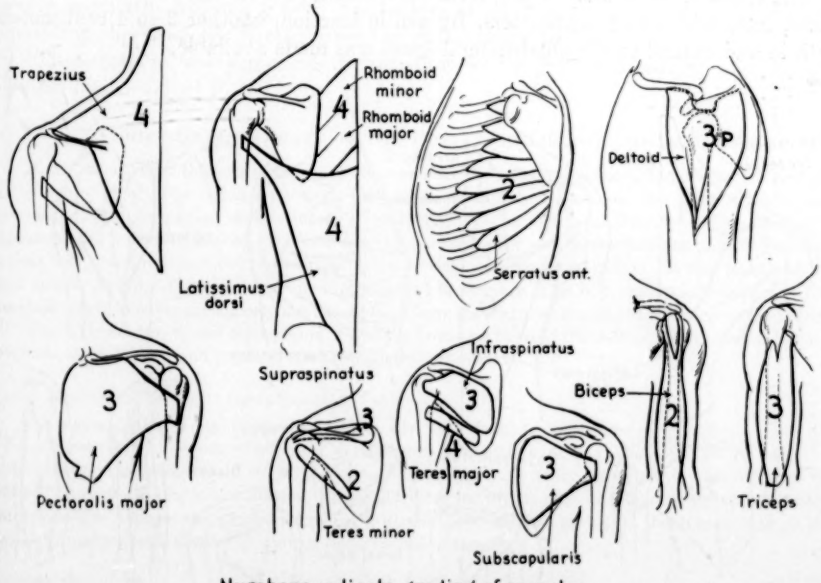

FIG. 2-B

Case 2

greater distances without compromise than any other axioscapular or axiohumeral muscle.

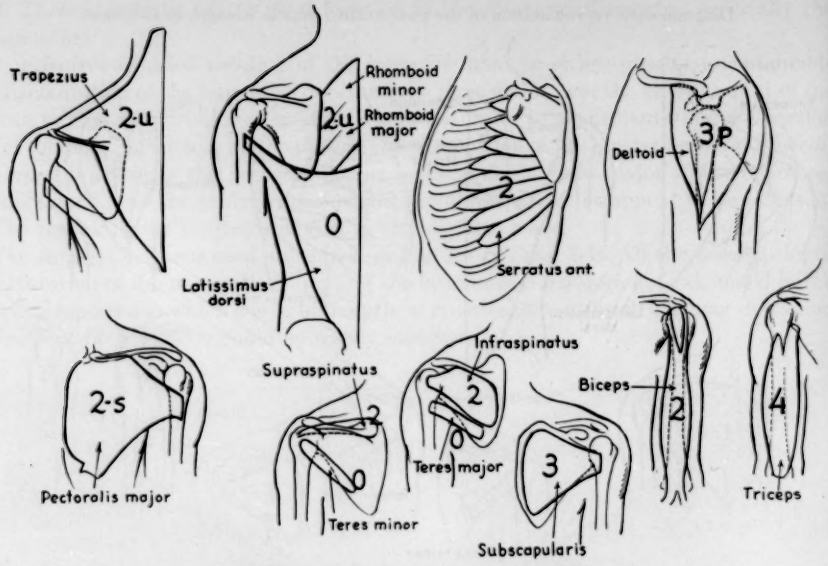

FIG. 2-C

Case 3

The trunk of the axillary nerve, from the quadrilateral space to its entrance into the deltoid, measured 6 to 8 centimeters. By gentle traction, another 2 to 4 centimeters of length in and central to the quadrilateral space was made available.

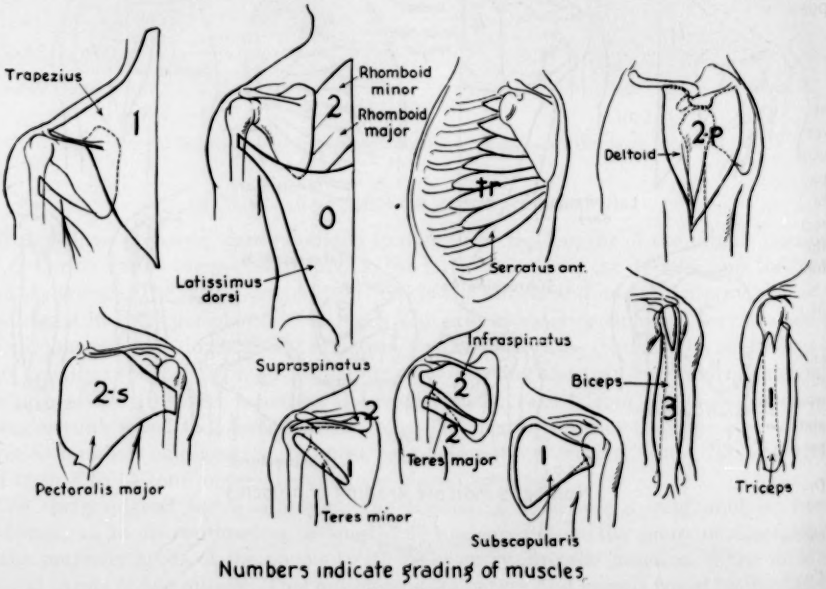

FIG. 2-D

Case 4

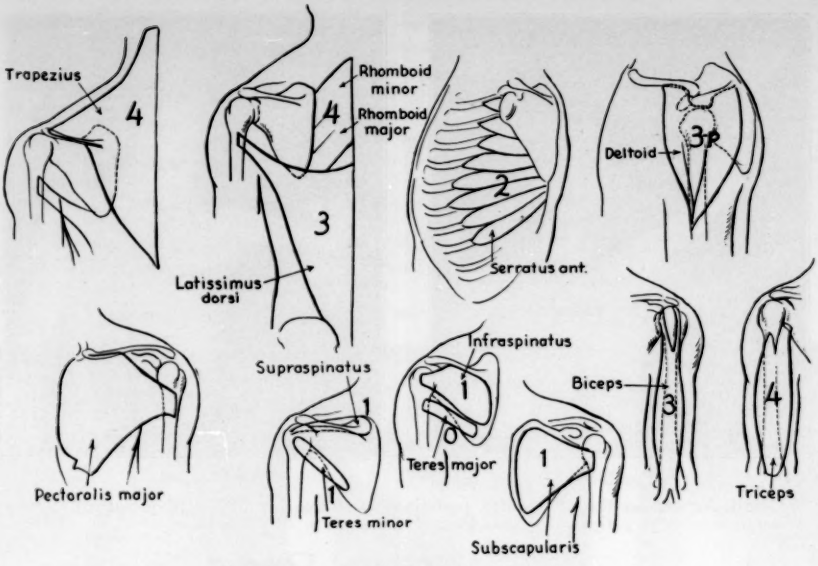

FIG. 2-E

Case 5

The branch of the radial nerve to the long head of the triceps averaged 3 to 5 centimeters in length. At least 5 to 7 centimeters of additional length could be obtained by separating this branch centrally from the radial-nerve trunk.

These cadaver measurements do not allow for the greatest elasticity and the greatest possible displacement in the living subject.

CASE 1. SHIFT OF THE ORIGIN OF THE POSTERIOR DELTOID TO AN ANTERIOR SITE

R. M., a boy, aged thirteen years at the time of the muscle transplantation, had contracted poliomyelitis at the age of eight. The residual paralysis included abduction inadequacy of the right shoulder; this was complicated by intermittent dislocation as a result of abduction, humeral atrophy and shortening, triceps weakness, and a semi-flail wrist. The case is analyzed here with special emphasis on muscle function. The patient was able to abduct the right arm only to 40 degrees prior to operation. At this point the humeral head usually became dislocated and the arm dropped to the side. This boy was operated upon in 1942 [6]. A tenodesis, performed by raising osteoperiosteal flaps from the bicipital groove, was unsuccessful in restraining the humeral head, but a later transplantation of the posterior third of the deltoid to an anterior site restored full, smooth abduction and repaired the pathological dislocation.

Muscle Examination Prior to Operation (Fig. 2-A)

The axioscapular group (trapezius, rhomboids, and serratus) were normal except that the serratus anterior allowed slight scapular winging. The latissimus dorsi and the teres major could not be detected. The supraspinatus was graded as + + +; the infraspinatus and teres minor were functioning, but were slightly weaker. The subscapularis was normal. The posterior third of the deltoid remained normal, but inhibited abduction. The biceps was graded as + + + (could hold against gravity); the triceps was + +. The pectoralis major (both divisions) showed only a trace of function.

Operative Procedure

A shift of the origin of the posterior deltoid to the acromion and the outer third of the clavicle was carried out on April 6, 1942.

Postoperative Care and Progress

The right arm was supported by a shoulder spica with the arm and forearm in the frontal plane. The upper half of the arm portion of the cast was removed after three weeks, and light massage and active motion

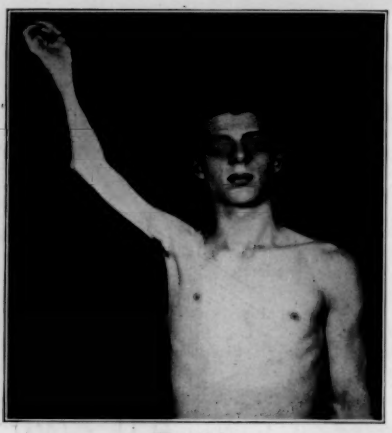

FIG. 3-A

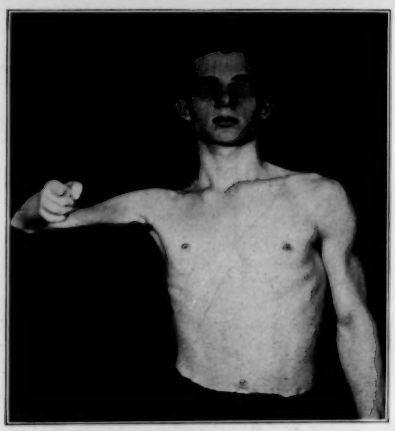

FIG. 3-B

Case 1. Appearance three years after posterior deltoid transplantation. (Reproduced, by permission, from *Surgery, Gynecology, and Obstetrics*, Vol. 84, p. 119, 1947.)

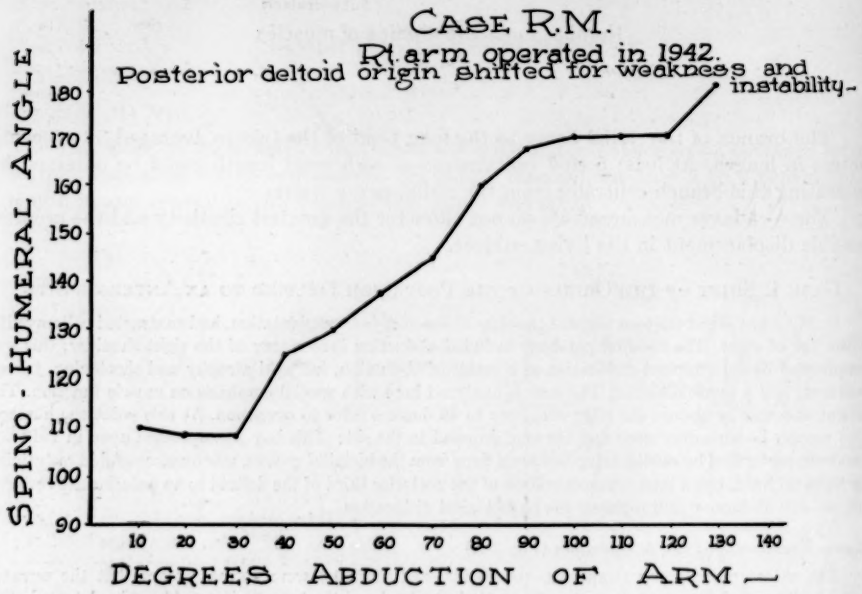

FIG. 3-C

The spinohumeral angle. These measurements were made in 1947, five years following the muscle transplantation.

were begun. The whole cast was removed after five and one-half weeks and the arm was supported upon an airplane brace. The patient could hold the arm at right-angle abduction against gravity at the end of six weeks, but he wore the brace for protection for an additional four months. The transplanted deltoid improved in function and underwent considerable hypertrophy.

The appearance of the patient in 1945 is shown in Figures 3-A and 3-B. It was estimated that the transplanted portion of the deltoid had become hypertrophied to at least three times its mass prior to operation. The biceps was atrophied as compared to the normal biceps on the left, but functioned normally against gravity. The triceps was still weak, but the trapezius, supraspinatus, serratus anterior, subscapularis, and rhomboids were normal or only slightly weakened. External rotation of the arm was markedly weakened

at all levels of abduction, but internal rotation was normal with the arm at the side and was excessive with abduction (due to the transplanted deltoid and to the subscapularis). Scapulohumeral relations (Fig. 3-C) were disturbed: The first 30 degrees of abduction were performed solely by scapular rotation, the next 60 degrees only by abduction of the humerus on the scapula. Motion beyond 90 degrees was performed by scapular rotation only.

When last seen in January 1949, almost seven years after the transplantation, the patient could hold his right arm at any degree of abduction and the motion could be performed smoothly against resistance.

Comment and Analysis

The excessive internal rotation during abduction, noted as an end result, was due in some measure to excessive anterior placement of the transplant.

Case 2. Multiple Two-Stage Transplantations at the Shoulder

Fig. 4-A

Fig. 4-B

Fig. 4-C

Fig. 4-A: Case 2. Preoperative photograph showing maximum abduction of both shoulders.

Figs. 4-B and 4-C: Postoperative range of motion.

Fig. 4-D: In this drawing the muscles which were transplanted are heavily shaded.

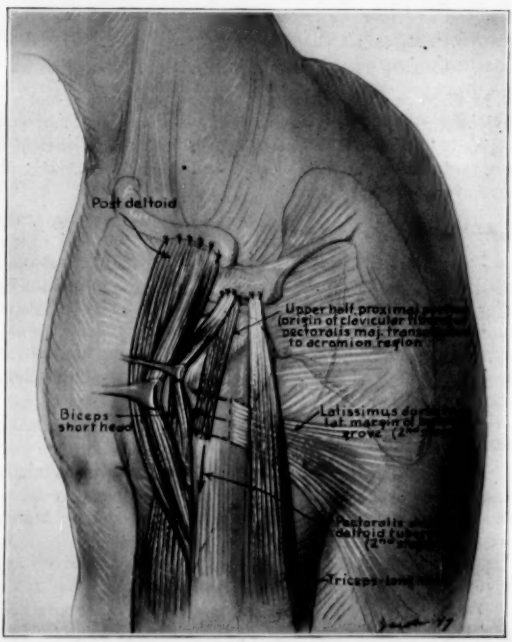

Fig. 4-D

K. S., a boy of six at the time of his operation, had had acute poliomyelitis four years previously. The residual paralysis resulted in loss in abduction at both shoulders and widespread weakness in the right lower extremity, necessitating bracing. Multiple muscle transplantations were carried out on the right upper extremity.

Muscle Examination Prior to Operation (Fig. 2-B)

The residual functional muscles were similar in the two shoulders, but the right shoulder was definitely the better. The patient controlled both scapulae well; the rhomboids, trapezius, latissimus dorsi, and teres major

were normal on both sides. Examination of the right shoulder revealed that the following muscles were either normal or a strong + + +: pectoralis major, triceps, supraspinatus, infraspinatus, teres minor, and subscapularis. The biceps was a strong + + and the serratus anterior was also estimated as + +. Although not detected by muscle examination, a functioning remnant of the posterior deltoid was observed at operation and was utilized in the transplantations. Extensive atrophy of the deltoid regions was present on both sides, and the patient was unable to actively abduct either arm more than 15 degrees (Fig. 4-A).

Operative Procedure (Fig. 4-D)

The operation on the right shoulder was carried out in two stages, as follows:

First stage—November 21, 1945

1. The proximal portion (origin of the clavicular fibers) of the upper half of the pectoralis major was transplanted to the acromion region.
2. The origin of the posterior deltoid remnant was shifted to the tip of the acromion and the outer fourth of the clavicle.
3. The origins of the long head of the triceps and the short head of the biceps were transferred to the tip of the acromion.

Second stage—December 14, 1945

1. The distal portion (insertion) of the clavicular fibers of the pectoralis major was transferred to the region of the deltoid tubercle.
2. The insertions of the latissimus dorsi and the teres major were transplanted over the lateral surface of the humerus to the lateral margin of the bicipital groove.

Postoperative Care and Progress

Postoperative support was by means of a plaster spica for the arm and body, with emphasis on external rotation and hyperabduction following the second operation. The upper half of the arm and forearm portion of the splint was removed two and one-half weeks after the second operation. Due to personality difficulties and a slightly subnormal mentality, the patient cooperated poorly with the physical-therapy technician and moved the shoulder and arm as he pleased. One month after the cast lid had been removed and six and one-half weeks after the second operation, nearly normal abduction and external rotation were present. However, the spica and arm support were not removed for another two months. Thereafter, use of the right arm was normal, including smooth, effortless abduction and rotation as the arm was elevated (Figs. 4-B and 4-C). This continued during a two-year observation period.

Case 3. Transplantation of the Origin of the Posterior Deltoid (First Stage) and of the Long Head of the Triceps at Its Origin (Second Stage)

M. C. M., a girl of six years at the time of operation, had contracted acute poliomyelitis eighteen months previously, resulting in extensive paralysis around the right shoulder, weakness in the left upper extremity, atrophy in both thighs, and imbalance in both feet. The right upper extremity was normal from the elbow downward, except for mild diffuse atrophy, and was highly abnormal above this point. The patient was above average in intelligence.

Muscle Examination Prior to Operation (Fig. 2-C)

The rhomboids, trapezius, latissimus dorsi, and serratus anterior were only fair, and allowed excessive scapular mobility and scapular winging. The supraspinatus and infraspinatus were good. The pectoralis major was fair and atrophic. Internal rotation by the subscapularis was fair; the biceps was rated "trace". The posterior deltoid functioned well; it served as an external rotator and adductor, being unopposed by the paralyzed middle and anterior thirds. The long head of the triceps was normal; the remainder of the triceps was slightly weakened. The patient was unable to abduct her arm more than 5 to 10 degrees in the initial range of motion (Fig. 5-A).

Operative Procedure

The operation was carried out in two stages. It was originally estimated that shift of the origin of the posterior deltoid at the right shoulder (performed on November 7, 1945) would be sufficient to secure effortless abduction. This proved not to be the case, and, on March 3, 1946, the origin of the long head of the triceps was shifted to the acromion region.

Postoperative Care and Progress

The right arm was supported for six weeks by an arm and body cast, and by an airplane brace for an additional six weeks. The child was then allowed to go for short periods without support. Since abduction power was rapidly lost and abduction was ataxic, the second-stage transplantation was then performed. Abduction support following the second operation was continued for four months on a bivalved arm and body

FIG. 5-A

Case 3. Preoperative photograph.

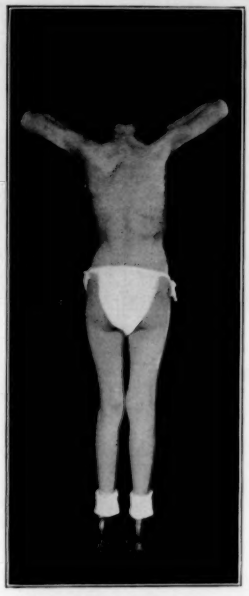

FIG. 5-B

Postoperative range of motion.

FIG. 5-C

spica, and for one and one-half months more on an abduction brace. During the thirty months since that operation, the patient has had smooth, effortless abduction. The result has been satisfactory (Figs. 5-B and 5-C).

Comment and Analysis

Although the patient is still unable to fix the scapula satisfactorily, function has been excellent, a result which may be explained in part by good power of the supraspinatus and infraspinatus. In addition, this patient was a slender girl, whose upper extremity weighed relatively little. When the scapula is held manually, the patient is unable to abduct the arm. The total period of observation following operation has been three years.

CASE 4. MULTIPLE TRANSPLANTATIONS IN ONE STAGE

D. J., a girl, aged fifteen at the time of her acute attack of poliomyelitis, had multiple muscle transplantations done about the right shoulder fifteen months later. When this patient was first seen, four months after the attack, multiple and generalized contractures inhibited all effective motion at the shoulder, elbow, hips, and knees. The ankles, feet, wrists, and hands were in poor position as a result of positional contractures. The contractures and immobilized joints slowly yielded to gentle stretching, traction, hot packs, and active motion during the eight-month period following hospitalization. Good to excellent function was obtained in the left upper extremity and the right lower extremity. The left lower extremity required bracing.

Just prior to operation. the patient was unable to elevate her right arm in the frontal plane, and active abduction was possible only to 45 degrees (Fig. 6-A). The chief inhibiting factors were the contracted, but functioning, lower two-thirds of the right pectoralis major and diffuse muscle weakness. Measurement of the scapulohumeral angle showed that both the scapula and the humerus participated in the limited abduction. Operation on the right upper extremity was undertaken in part for the release and reimplantation of the insertion of the contracted sternocostal portion of the pectoralis major.

Muscle Examination Prior to Operation (Fig. 2-D)

Active abduction could be performed only to 45 to 50 degrees. Scapular movement was ineffectual and was limited by contractures. The serratus anterior was "trace"; the trapezius and rhomboids were contracted and were graded as + and + +, respectively. The latissimus dorsi had no power and the teres major was estimated at + +. The supraspinatus and infraspinatus were graded at + +. The subscapularis was +. The posterior portion of the deltoid was considerably stronger than the supraspinatus and infraspinatus, being graded + + and at times + + +. The biceps was adequate (+ + +), the triceps very weak (+).

FIG. 6-A

FIG. 6-B

Fig. 6-A: Case 4. Preoperative range of abduction.
Fig. 6-B: Postoperative abduction.
Fig. 6-C: In this drawing the transplanted muscles are heavily shaded.

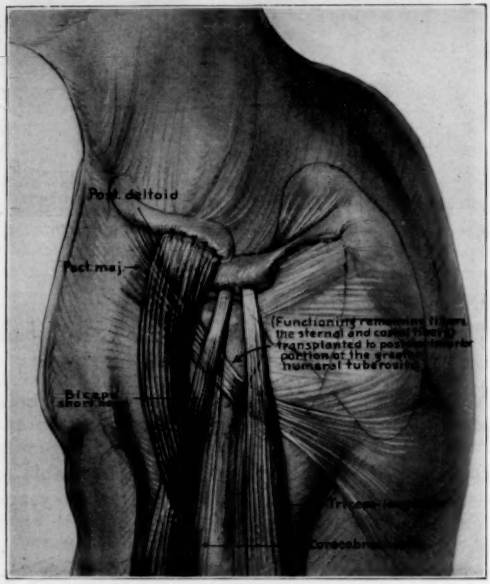
Post. deltoid
Pect. maj.
(Functioning remaining fibers of the sternal and costal fibers) transplanted to postero-inferior portion of the greater humeral tuberosity
Biceps
Coracobrachialis

FIG. 6-C

No clavicular fibers of the pectoralis major remained; the costomanubrial fibers were contracted but functioning (+ +). The forearm was more nearly normal, except that the pronators and supinators were weak and slightly contracted and opposition of the thumb was not possible. There was some weakness of the intrinsic muscles of the hand, and atrophy was seen, but good function remained in the long flexors and extensors.

Operative Procedure

On January 20, 1947, as a single-stage operation, the following transplantations were performed (Fig. 6-C):

1. The origin of the posterior deltoid was shifted to the region of the acromion.
2. The origins of the long head of the triceps, short head of the biceps, and the coracobrachialis were transplanted to the acromion.
3. The insertion of the pectoralis major was transferred to the postero-inferior portion of the greater tuberosity of the humerus.

Postoperative Care and Progress

The arm was held by a body-and-arm cast in hyperabduction and external rotation, about level with the head in the lateral plane of the body. Active and passive motion of the arm and shoulder was begun in three weeks.

At three and one-half weeks, another body-and-shoulder cast was applied with the arm in 90 degrees of abduction in the frontal plane, and active motion was continued. In two more weeks (five and one-half weeks after operation), an airplane brace was utilized for support; this apparatus was discarded three months after operation.

Seven weeks after operation, active external rotation was good. The patient was barely able to support the arm against gravity at 30 to 50 degrees of abduction. At sixteen weeks she could hold the arm at 50 degrees for five minutes; at twenty-two weeks she could abduct it to 80 degrees with but little scapular motion (Fig. 6-B).

Measurement of the scapulohumeral angle showed most of the motion to be at the glenohumeral joint for the first 40 degrees; thereafter slight scapular rotation took place, greatly restricted by contractures. The transplants were all functioning, but with restricted range due to muscle fibrosis.

FIG. 7-A

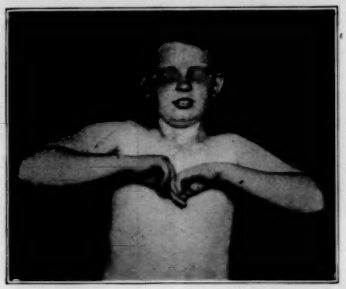

FIG. 7-B

Fig. 7-A: Case 5. Preoperative photograph.

Figs. 7-B and 7-C: Postoperative range of motion.

FIG. 7-C

Comment and Analysis

Tension of the biceps, when abduction was performed with the elbow flexed, added to abduction power. This case is an example of improvement in range and power in abduction in a shoulder which was extensively damaged. The period of postoperative observation has been three years.

CASE 5. MULTIPLE TRANSPLANTATIONS IN ONE STAGE

T. B., a boy, aged nine and one-half years at the time the muscle transplantation was performed, had extensive paralysis from poliomyelitis, contracted twenty-four months earlier. Shoulder movement on both sides had been inadequate for several months following the attack. By nine months after the acute phase, however, spontaneous abduction had returned at the left shoulder, associated with ease of fatigue. The abdominal muscles were almost completely paralyzed, and extreme quadriceps weakness was present at the left knee. The left shoulder returned spontaneously to full use fifteen months after the acute attack, and thereafter was relatively free from fatigue. Abduction inadequacy of the right shoulder had been stationary for over a year (Fig. 7-A).

Muscle Examination Prior to Operation (Fig. 2-E)

Active abduction at the right shoulder could be performed to 20 to 30 degrees only. The muscle examination showed poor ability to fix the scapula, due to weakness (+ +) of the serratus anterior, which allowed scapular winging. The trapezius was normal. The supraspinatus, infraspinatus, and teres minor were rated as +, the teres minor often being not detected. The teres major was very weak, but the latissimus dorsi was + + +. The triceps and pectoralis major were normal. The biceps and posterior deltoid were + + +. The middle and anterior portions of the deltoid were non-functioning, but the posterior portion was active. There were no contractures.

Operative Procedure

On November 14, 1946, the following operation was carried out on the right (Fig. 7-D):

1. The origin of the posterior deltoid was transplanted anteriorly.
2. The origins of the long head of the triceps and short head of the biceps were transplanted to the acromion.
3. The latissimus dorsi was transplanted around the humerus so it would be an external rotator.

The teres major was non-elastic, and two inches was cut from its tendinous portion.

Postoperative Course and Result

The right arm was supported in hyperabduction and external rotation for five weeks. During the fifth week, active exercises were begun. A second abduction plaster, with the arm in the frontal plane at shoulder level, was applied during the sixth week and worn for the next five weeks. It was then replaced by an airplane brace, which was worn intermittently for sixty days. At four weeks the patient had excellent active external rotation when the arm was supported at 70 to 100 degrees. From six weeks until seven weeks, spontaneous

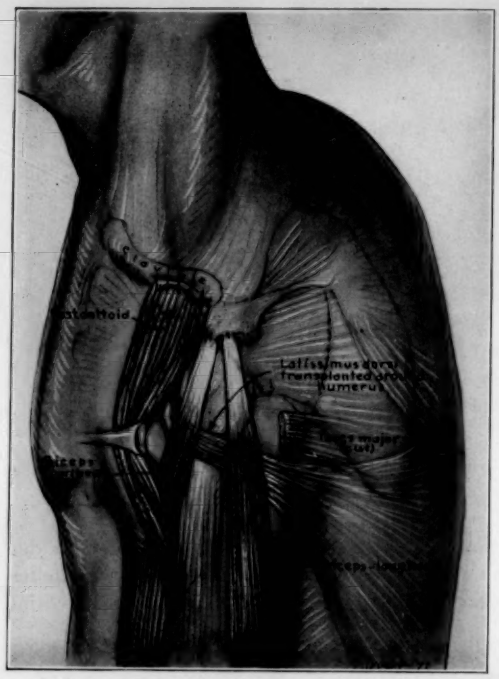

FIG. 7-D

In this drawing the muscles which were transplanted are heavily shaded.

abduction to almost any position was possible. At this time he was discharged from the Hospital, and thereafter he used the abduction brace only intermittently and neglected his exercises. When the patient was seen, seventeen weeks after operation, abduction could be performed only to 40 degrees. He was readmitted to the Hospital for physical therapy and was urged to wear the abduction brace continuously. When he was discharged at twenty-three weeks, abduction could be performed easily with the triceps at maximal contraction (obtained by an opposing frontal load), but was uncertain without such triceps action. The patient has slowly improved and, while full abduction can be performed often, it becomes diminished as a result of fatigue (Figs. 7-B and 7-C). Another operation was planned to shift the pectoralis major to the postero-inferior humeral tuberosity, but this was not permitted by the parents.

DISCUSSION

The outcome in all five cases has been good, with results superior, both in range of motion and in satisfaction to the patient, to those which would have been obtained by shoulder arthrodesis. Some qualification of this statement is necessary in two of the cases. Motion in abduction was limited to a little less than 90 degrees in Case 4, due to unyielding contractures of the muscles about the scapula. Ease of fatigue was demonstrated in Case 5; this result was probably associated with poor scapular fixation, due chiefly to a weak serratus anterior. Utilization of the pectoralis major for transplantation would have improved the final outcome, but the second operation was not permitted. The results in Cases 1, 2, and 3 were ideal.

Evaluation of the abduction and elevating power was always made with the elbows in full extension for the purpose of diminishing whatever aid a normally placed biceps would have in increasing abduction, and to provide a maximum length of lever arm and the maximum pull of gravity against the muscles of abduction. Without exception, the reverse situation (shoulder abduction performed with the elbow flexed, utilizing the shoulder-stabilizing influence of the biceps) was more adequately accomplished and greater endurance was achieved in all five cases.

When the posterior deltoid remains available for anterior transplantation and when some or all of the auxiliary muscles are functioning, the chances of a successful outcome are better.

The differences between spontaneous recovery from widespread paralysis and the lack of such recovery, and consequently the necessity for surgical transplantation, hinge upon the recovery of at least a portion of the normal anterior and middle deltoid. The equivalent is secured by muscle transplantation.

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FACTORS DETERMINING THE DEPOSITION AND DEMINERALIZATION OF BONE

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In a consideration of pathological changes in bone, it should be realized that we are dealing with a supporting structure and that we should not speak of diseases of bones, but rather of the effects of diseases on bones. These effects are of two types, causing either (1) the deposition of bone, or (2) the demineralization (absorption) of bone. As observed roentgenographically, there is osteosclerosis and osteolysis, or bone formation and bone destruction. Our study, therefore, leads to an analysis of the factors behind these two processes and to an attempt to classify all conditions affecting bones on the basis of bone formation or bone destruction.

CHEMISTRY OF BONE

The constituents of bone, as determined by analysis, are best illustrated diagrammatically (Fig. 1). The elements of which bone is composed are deposited as a crystalline

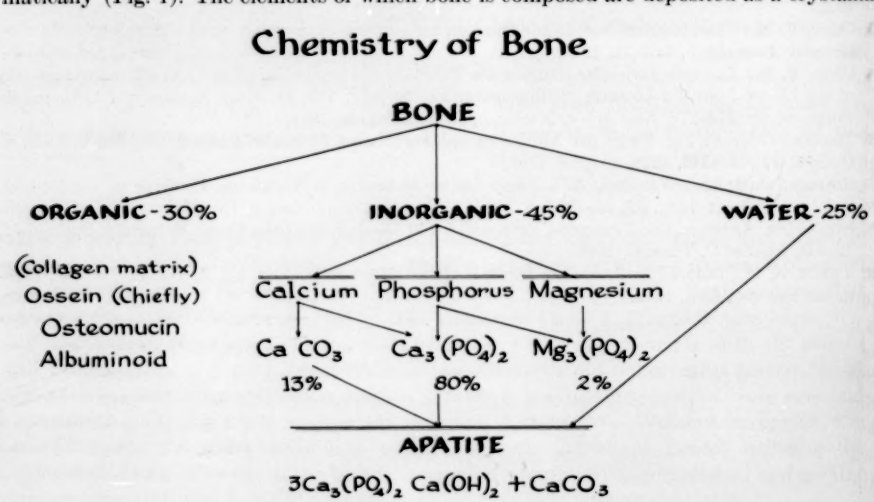

FIG. 1

compound approximating the chemical formula of apatite, of which the important components are calcium and phosphorus [2]. The metabolism of these elements will be considered separately.

Factor 1. Metabolism of Calcium

Calcium occurs in the blood serum as ionized calcium (immediately available for deposition in bone) and as protein-bound calcium, combined either with albumin or with globulin [9]. The level of calcium in the blood depends primarily upon its absorption from the intestine, which absorption is reduced by (1) decreased calcium intake in the food; (2) impaired saponification of fat (as in celiac disease or steatorrhoea); (3) the formation of an insoluble compound (tricalcium phosphate) with phosphorus, which is excreted

into the intestine in kidney disease (renal rickets); (4) a deficiency of vitamin D in the diet; and (5) increased alkalinity of the intestinal contents. The effect of parathormone on the levels of serum calcium and phosphorus will be discussed later.

Factor 2. Metabolism of Phosphorus

Phosphorus is found in the blood serum as inorganic phosphate (available for combination with calcium to form bone) and as organic phosphorus, in the form of (1) phosphoric esters (requiring hydrolysis by phosphatase before entering into bone formation); (2) lipid phosphorus, such as lecithin; and (3) nucleic acid phosphorus which occurs only in cells and is negligible except in leukocytosis or leukaemia [2]. The level of serum phosphorus is *increased* in (1) alkalosis due to pyloric obstruction or hyperventilation associated with reduced urinary excretion of phosphorus; (2) in severe renal insufficiency, in which the clinical condition is known as renal rickets; (3) in reticulocytic anaemia and leukaemia; and (4) in tetany. Serum phosphorus is *decreased* in (1) diabetic acidosis following the injection of insulin, (2) the active stage of rickets, and (3) hyperparathyroidism.

Factor 3. Parathormone

The internal secretion of the parathyroid gland raises the level of calcium in the blood serum at the expense of the skeleton, which serves as both a calcium and a phosphorus bank. This effect may be secondary to the other action of parathormone, which is to lower the level of serum phosphorus by increasing the urinary excretion of phosphorus [9]. The normal level of serum phosphorus is then restored by the withdrawal of phosphorus (and the calcium which is combined with it) from the bones, leading to the clinical entity of osteitis fibrosa cystica. Whether the increase in number of osteoclasts which are found in this condition is due to the action of parathormone or is merely a result of rapid bone absorption, is debatable (see Factor 8).

Factor 4. Local Variations of Hydrogen-Ion Concentration (pH) in or around Bones

Because the combination of calcium and phosphorus which comprises bone is insoluble in a neutral or alkaline medium, the pH in the region of new-bone formation is of primary importance. Experimentally it has been shown by Swenson that, for several days following a fracture, the hematoma has a low pH (acid) which causes absorption of bone at the site of fracture and a local increase in the concentration of ionized calcium and phosphorus. Subsequently, the hematoma becomes alkaline and the precipitation of calcium is favored. Similarly, in the case of osteomyelitis, the early hyperaemia and oedema decrease the pH, leading to absorption of bone, after which the constriction of blood vessels by contracting scar tissue reduces the blood flow, raising the pH and causing the deposition of bone (involucrum).

Factor 5. Phosphatase

Phosphatase is an enzyme which hydrolyzes phosphoric esters, with the liberation of ionized phosphate which is available for combination with calcium. As demonstrated by the staining technique of Gomori, this enzyme is found in the following sites: cartilage undergoing calcification, osteoblasts (including malignant osteogenic tumors), intestinal epithelium, the epithelium of the proximal convoluted tubules of the kidney, the endothelial cells of the liver and spleen, bladder epithelium which has been transplanted to fascial spaces, and the peripheral zone of necrotic tuberculous granulation tissue [5]. An elevated level of serum alkaline phosphatase is a sign of increased bone metabolism which occurs in hyperparathyroidism, osteitis deformans (Paget's disease), carcinoma of the prostate with metastases to bone, other malignancies with osteoplastic metastases, osteogenic sarcoma, and rickets [9]. An increased acid phosphatase is pathognomonic of

carcinoma of the prostate with bone metastases. Alkaline phosphatase is excreted in the bile and its serum level is, therefore, raised in jaundice or liver damage.

Factor 6. Vitamin Deficiency

Vitamin A is essential to epiphyseal-cartilage cells for the cycle of growth, maturation, and degeneration in the formation of enchondral bone [8]. A deficiency of this vitamin does not affect periosteal bone growth.

Vitamin-C deficiency will be discussed in the section on protein metabolism.

Vitamin-D deficiency produces the various clinical types of rickets (foetal, infantile, and late rickets). It is also, in part, responsible for osteomalacia, which is essentially an adult form of rickets. The characteristics of vitamin-D deficiency include: defective calcification of growing bone, hypertrophy of epiphyseal cartilages, a zone of preparatory calcification which is composed of calcium-poor osteoid tissue, softness and pliability of bones, cupping of the epiphyseal lines, and a low calcium and phosphorus content of bones. Analysis of the blood serum usually shows a low phosphorus content, an elevated alkaline phosphatase, and a normal calcium content (except in tetany, when the calcium is reduced). Vitamin D may also be essential to an adequate absorption of calcium in the intestines, although its major role is to promote the conversion of cartilage into bone at the epiphyseal lines.

Factor 7. Protein Metabolism

Any impairment of protein metabolism results in the deficient formation of the preosseous substance in which calcium and phosphorus are deposited to form bone.

Vitamin C is essential for the formation of the various types of collagen, including bone matrix. An absence of this vitamin is associated with deficiency in the laying down of a sound matrix in which ossification can occur. In a similar manner, in the scorbutic individual, the capillaries show increased fragility because of a deficiency of collagen formation. Collagen in the form of cementum normally renders the intercellular intervals of the capillaries impervious to the blood. Osteomalacia, which is seen in persons on a highly deficient diet, is related not only to a lack of protein, but also to a failure of normal collagen formation due to the absence of vitamin C.

Other clinical conditions resulting from an impairment of protein metabolism include the osteoporosis of old age, postmenopausal osteoporosis, and the generalized decalcification which accompanies immobilization of fractures and the associated prolonged recumbency [1]. In the latter case, the absence of the functional stimulus of activity apparently reduces the formation of bone matrix. Calcium continues to be withdrawn from the skeleton at the normal rate; but, since the deposition of new bone is decreased, the excess calcium is excreted by the kidneys, frequently causing the formation of kidney stones.

Factor 8. Activity of Cells

The principal cells which appear to be involved in the processes of bone formation and absorption are osteoblasts, osteocytes, and osteoclasts. The osteoblast is an embryonic type of cell which arises by a differentiation of fibroblasts. Its function is generally considered to be the secretion of preosseous substance in the form of bone matrix and of phosphatase. Leriche and Policard assigned a passive role to osteoblasts and regarded the formation of bone as a purely biochemical process. Osteocytes represent a mature stage of osteoblasts which, after their secretory activities have terminated, remain imprisoned in the newly formed bone, where they continue to lead a quiet existence.

About the origin and function of osteoclasts, there exists a wide variation of opinion. The traditional view is that the osteoclast (as its name implies) is a bone-destroying cell of uncertain origin which arrives at a field of rapid bone absorption, takes an active part in this process, and suddenly disappears at the conclusion of the absorptive stage. Thus,

TABLE I

CLASSIFICATION OF DISEASES IN BONES

A. *Osteolysis*

1. Generalized demineralization
   (a) Senile
   (b) Menopausal
   (c) Osteopsathyrosis (fragile bones)
   (d) Hyperparathyroidism (osteitis fibrosa cystica)
   (e) Hyperthyroidism
   (f) Renal rickets
   (g) Osteomalacia

2. Localized osteolysis
   (a) Post-traumatic bone atrophy (Sudeck)
   (b) Bone cyst
   (c) Echinococcus cyst
   (d) Xanthomatosis (Schüller-Christian)
   (e) Eosinophilic granuloma
   (f) Gaucher's disease
   (g) Fibrous dysplasia
   (h) Neurofibromatosis

3. Destructive inflammatory lesions
   (a) Acute osteomyelitis
   (b) Chronic granulomata
      (1) Tuberculosis
      (2) Coccidioides
      (3) Actinomycosis
      (4) Sporotrichosis
   (c) Syphilis (gumma)

4. Osteolytic primary bone tumors
   (a) Giant-cell tumor
   (b) Osteolytic sarcoma
   (c) Multiple myeloma

5. Metastatic tumors in bone
   (a) Breast carcinoma
   (b) Thyroid carcinoma
   (c) Lung carcinoma
   (d) Hypernephroma

B. *Osteosclerosis*

1. Generalized sclerosis
   (a) Osteopetrosis (marble bones)
   (b) Osteopoikilosis (spotted bones)

2. Localized sclerosis
   (a) Melorheostosis (Léri)
   (b) Neuro-arthropathy (Charcot)

3. Productive inflammatory lesions
   (a) Chronic osteomyelitis
   (b) Chronic sclerosing osteitis
   (c) Syphilitic periostitis
   (d) Brucellosis

4. Sclerosing primary bone tumors
   (a) Osteoma
   (b) Osteochondroma
   (c) Osteoblastic sarcoma

5. Sclerosing metastatic bone tumors
   (a) Prostatic carcinoma
   (b) Breast carcinoma (rare)

C. *Mixed Sclerosis and Lysis*

1. Osteitis deformans (Paget)

2. Chronic bone abscess (Brodie)

3. Endothelial myeloma (Ewing)

parathormone is thought by some writers to act by a stimulation of osteoclasts. According to the syncytial theory of connective tissue [4] which was advanced by Hansen in 1899 and subsequently modified by Häggqvist (1928) and by Hertz (1936), osteoclasts "are not the cause of the dissolution of the bone but represent in themselves the final stage of a local process of bone dissolution". Under such conditions, osteoclasts result from the breaking down of bone trabeculae and the liberation of protoplasmic masses (osteocytes), with amitotic division to form multinucleated giant cells which lie in the lacunae of dissolving bone. Later these giant cells divide and become connective tissue of embryonic type, which may again be differentiated into osteoblasts and produce new bone.

Factor 9. Erosion Effects of Invading Tissues

Acute pyogenic infections cause local absorption of bone by the pressure of a rapidly forming purulent exudate, as well as by a local hyperaemia which lowers the pH and results in decalcification. The chronic granulomata, such as in tuberculosis, by pressure and by a strangling of the blood supply of the bone trabeculae, gradually destroy the

surrounding cancellous bone. Here also decalcification follows local hyperaemia and the immobilization of the painful joint by muscle spasm.

Neoplasms destroy bone by the pressure of their expanding growth, as seen in bone cysts and giant-cell tumors. Direct infiltration and replacement of bone is characteristic of malignant tumors, either primary or metastatic. If the cells of the neoplasm are inherently osteogenic, new and atypical bone is formed. More difficult of explanation is the reactive new-bone formation which is seen in Ewing's tumor and in osteoid osteoma.

CLASSIFICATION OF DISEASES IN BONES

Because the two fundamental alterations which are possible in the skeleton involve the deposition (sclerosis) of bone and its demineralization (absorption or lysis), one may classify the more common conditions affecting bones under the headings of sclerosis and lysis (Table I). Such a classification is not related to the etiology, but merely to the morphology of the pathological processes which are found in bones.

SUMMARY

A rational approach to the study of pathological changes in bone involves an analysis of the factors which influence the two fundamental processes of bone deposition and demineralization. Upon such a basis, a classification of the diseases which affect bones is submitted. As the chief reliance must often be placed upon the roentgenogram, the value of which lies in the portrayal of variations in the density of bones, such a classification may be used as a chart of differential diagnosis.

NOTE: Grateful acknowledgment is made to Dr. J. B. deC. M. Saunders for his advice and generous assistance throughout this study.

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CLINICAL MANIFESTATIONS OF CONGENITAL NEUROFIBROMATOSIS *†

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Von Recklinghausen published, in 1882, a monograph concerning a disease process which has since borne his name. He described the relationship of the peripheral nerves to cutaneous and subcutaneous tumor nodules (Fig. 1), and attributed their origin to some abnormality in the peripheral-nerve endings. Gould, however, in 1918, pointed out that our conception of the disease had undergone a definite change and that closer investigation had brought to light additional features. He described the additional clinical manifestations of skin pigmentation, mental deficiency, skeletal changes, and joint changes. From this he concluded "that the disease can no longer be looked upon as a disease of the peripheral nerves, but of the whole nervous system, in which one or more of the ductless glands may be concerned".

The importance of these multiple clinical manifestations to the orthopaedic surgeon has increased with the passing years. Weiss, a dermatologist, in 1921 first described the high incidence of scoliosis in von Recklinghausen's disease; he gave credit to Engman, another dermatologist, for this observation. Brooks and Lehman, in 1924, were the first to describe associated abnormalities of growth and the presence of subperiosteal bone cysts, which they felt resulted from growth of the tumor tissue. They concluded that these two manifestations and scoliosis could be considered as characteristic of von Recklinghausen's neurofibromatosis as the manifestations in the skin and nerves. Ducroquet reported, in 1937, the presence of congenital pseudarthrosis of the tibia in neurofibromatosis. This relationship and the presence of congenital bowing were described later by Barber and by Green and Rudo. The latter authors presented a case in which an intra-osseous neurofibroma was demonstrated. Moore, in a paper read to The American Orthopaedic Association in 1940, described localized hypertrophy as well as congenital pseudarthrosis. He felt that enough evidence had accumulated to justify the existence of a causal relationship of the nerve lesion to the hypertrophy.

FIG. 1

Typical example of multiple subcutaneous tumor nodules, as described in 1882 by von Recklinghausen. Note also the numerous *café au lait* spots.

With this background of knowledge, a clinical study of current cases was instituted by the author four years ago; a total of forty-six patients have been encountered who presented features which can be considered compatible with this type of process. Interest

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, New York, N. Y., February 14, 1950.

† The skeletal survey in some of these patients was aided by a grant from the Phillips Foundation to the Mallinckrodt Institute of Radiology, St. Louis.

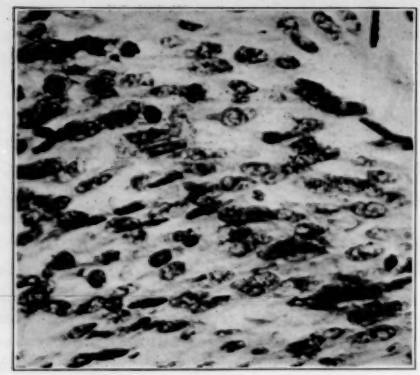

FIG. 2-A

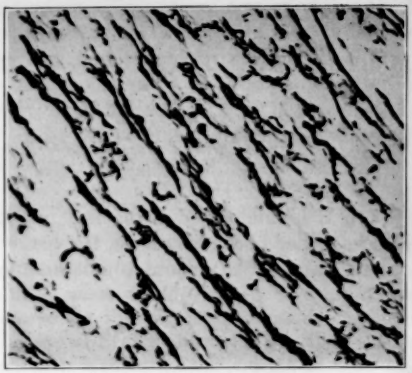

FIG. 2-B

Fig. 2-A: Malignant tumor arising from twelfth intercostal nerve, classified at first as a neurofibrosarcoma.

Fig. 2-B: Silver stain of tumor shown in Fig. 2-A. Reticulin pattern suggests Schwann sheath origin, on the basis of which the classification was changed to malignant schwannoma.

was first stimulated by a patient who showed typical subcutaneous neurofibromatous nodules and many *café au lait* spots, and who also presented evidence of a large deep-seated soft-tissue tumor mass opposite the left twelfth rib. Total excision of this mass was finally accomplished on the third attempt; this required removal of the entire twelfth rib

FIG. 3-A

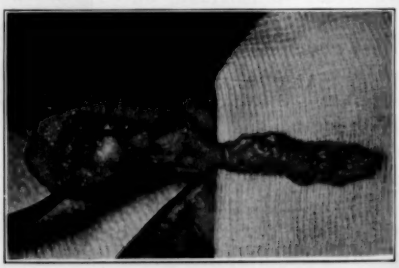

FIG. 3-B

Fig. 3-A: Congenital soft-tissue hypertrophy of right index finger and middle finger.

Fig. 3-B: Soft-tissue hypertrophy consisted of large tortuous nerves and nodular tumor masses.

FIG 3-C

FIG. 3-D

Fig. 3-C: Soft-tissue tumor involved adjacent portion of palm, in which corresponding interdigital nerve was hypertrophied.

Fig. 3-D: Appearance of hand six months after third operation; soft-tissue tumors were removed and deformity was corrected.

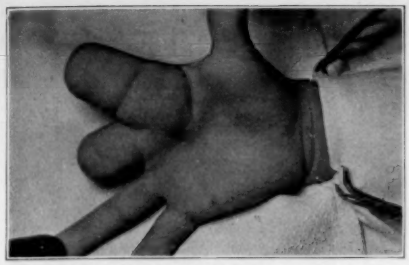

FIG 4-A

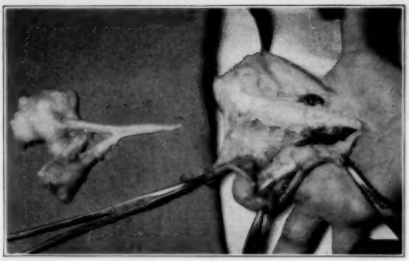

FIG. 4-B

Fig. 4-A: Involvement similar to that shown in Fig. 3-A, in which the two distal phalanges had previously been amputated from involved digits. Note extension of tumor mass into the palm.

Fig. 4-B: Extensive tumor was excised in a single operation. Soft tissue has been removed from proximal portion of inter igital nerve to show its change from normal size to marked hypertrophy at proximal margin of the tumor mass.

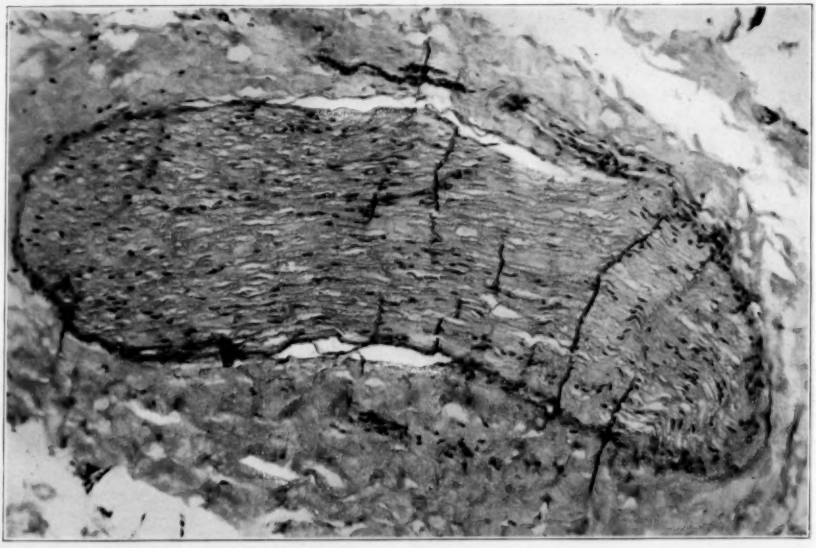

FIG. 4-C

Low-power magnification of hypertrophied nerve encountered in tumor mass.

and the adjacent portion of attached pleura. The tumor was thought to have arisen from the twelfth intercostal nerve, and microscopic study proved it to be malignant. The original classification was neurofibrosarcoma (Fig. 2-A), but, on subsequent review by Ackerman, this classification was changed to malignant schwannoma (Fig. 2-B). The patient has shown no indication of tumor recurrence, three and one-half years after surgery.

The next patient had congenital hypertrophy of the right index finger and middle finger (Fig. 3-A), with a large soft-tissue tumor mass occupying the distal half of the corresponding portion of the palm. The digital enlargement consisted primarily of soft-tissue hypertrophy in which was located large tortuous nerves and nodular tumor masses (Fig. 3-B). On dissection of the soft-tissue mass in the palm, the interdigital nerve supplying the adjacent surfaces of the index finger and middle finger was found to be enlarged

many times its normal size (Fig. 3-C). Proximal to the tumor mass this nerve was normal in size, but it enlarged sharply at a point which corresponded exactly to the proximal

FIG. 5-A

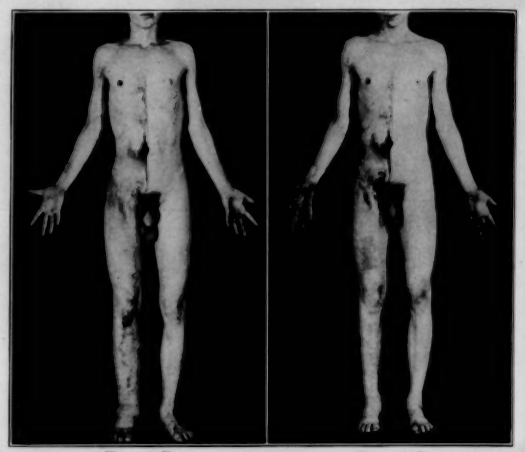

FIG. 5-B FIG. 5-C

Fig. 5-A: Heavy unilateral pigment deposit, classified as naevus lateralis. Note slight hypertrophy of corresponding index finger and middle finger.

Fig. 5-B: Pigmentation was accompanied by hypertrophy of subcutaneous tissue and primary or secondary lymphatic changes in the lower extremity on the corresponding side.

Fig. 5-C: Enlargement of right leg and foot was reduced in a series of four operations, in which hypertrophied subcutaneous tissue was excised.

FIG. 5-D

Thick-walled vein found in abundance in excised soft tissue. This was a very common finding in all cases of soft-tissue hypertrophy.

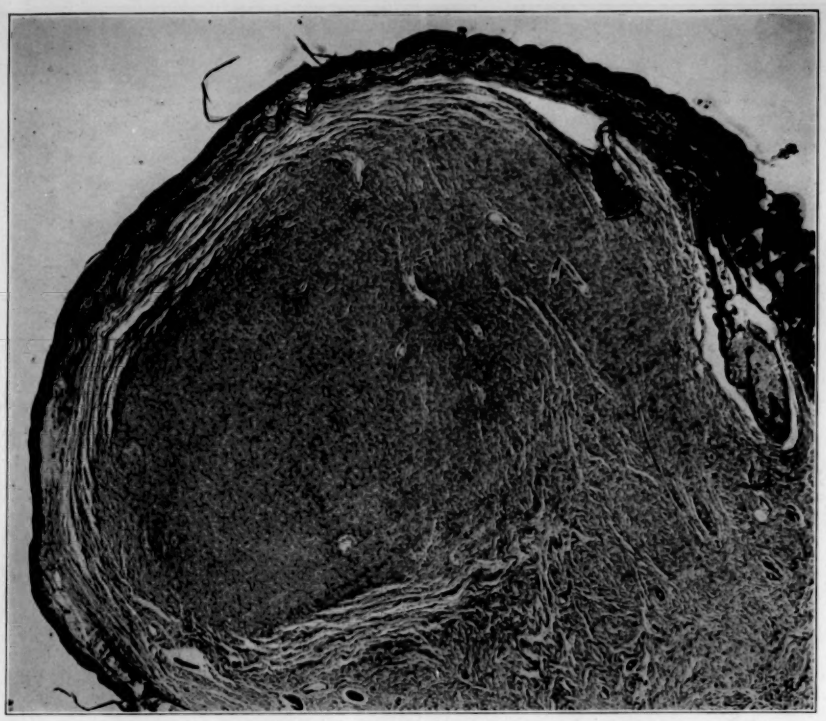

FIG. 6

Low-power magnification of typical subcutaneous neurofibromatous nodule, consisting of nerve tissue covered by areolar tissue and skin.

margin of the soft-tissue tumor. It seemed reasonable to assume, therefore, that the local soft-tissue hypertrophy was directly connected with, or the result of, this peripheral-nerve tumor. After three operations, the tumors were removed and the fingers returned to essentially normal size and function (Fig. 3-D), although excision of the nerve resulted in some impairment of sensation in the involved fingers.

Two such cases have been encountered, and the findings were identical. In one patient the second and third phalanges of the two involved digits had been amputated previously because of the associated skeletal hypertrophy (Figs. 4-A and 4-B).

In cases of this type and in those with the plexiform type of soft-tissue hypertrophy, the presence of nerve tissue and at times of nerve-sheath hypertrophy is easily demonstrated (Fig. 4-C). In many others, however, in which the soft-tissue hypertrophy is diffuse in character and usually involves an entire extremity, it is impossible to prove the presence of excess nerve tissue by microscopic study. Thannhauser pointed out that the nerve fiber itself may disappear very early in a neurofibroma; he believed: "Whorls of spindle cells, if present in the fibrous tissue, indicate the neurofibromatous origin of the involvement". Other microscopic characteristics of these tissues have been found to be quite similar. Generalized increase in connective tissue and fibrous-tissue cells, and a diffuse increased vascularity as evidenced by numerous thick-walled veins (Fig. 5-D), represent changes which have been found common in all instances. Since similar microscopic changes were present in all instances of soft-tissue hypertrophy in this series, with or without demonstrable neurofibromata, it would seem reasonable to assume that all may have a common etiology in a developmental defect of the nervous system.

FIG 7-A

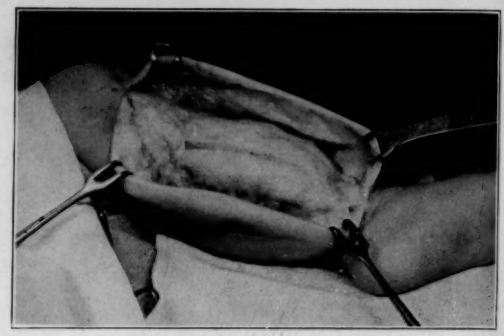

FIG. 7-B

Fig. 7-A: Diffuse soft-tissue hypertrophy and increase of three-quarters of an inch in length of left lower extremity.
Fig. 7-B: Typical tumor mass of hypertrophied soft tissue, exposed at one stage of the operative procedure.
Fig. 7-C: Excision of tumor mass almost completed. Note that it is not encapsulated and is superficial to the deep fascia.

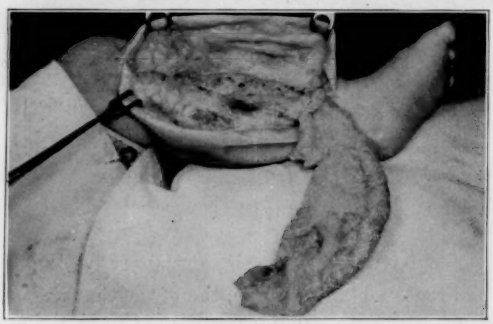

FIG. 7-C

Fig. 7-D: Photograph after four operations. Hypertrophied soft-tissue masses were excised, and relatively normal size and contour were restored.

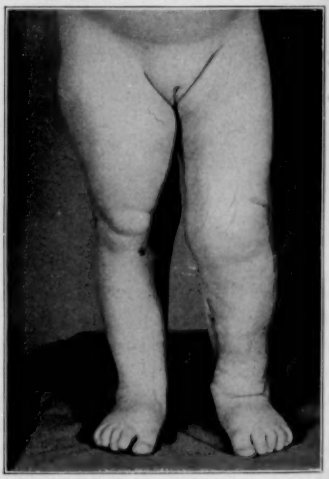

FIG. 7-D

In this series of forty-six cases, the various clinical characteristics have been classified under five major headings: cutaneous, subcutaneous, skeletal, vascular, and lymphatic (Table I). Each heading will be considered separately, although they practically never exist individually and many different types of involvement are usually encountered in the same patient. Associated mental deficiency, described by Gould, has not been prominent in this series and was suspected in only one case.

Cutaneous Manifestations

The principal skin manifestation is represented by some abnormality in pigmentation. *Café au lait* spots (Figs. 1, 9, and 13-B) have been recognized as a part of the clinical syndrome associated with neurofibromatosis, and were encountered in thirty-three cases

Fig. 8-A: Hypertrophy of leg and increased length, associated with plexiform type of neurofibromatosis.
Fig. 8-B: Increased length (one and one-half inches) of tibia and fibula and loss of normal soft-tissue contour in involved extremity.
Fig. 8-C: Low-power magnification of enlarged nerve fiber removed from this plexiform neurofibromatosis.

FIG. 8-A

FIG. 8-B

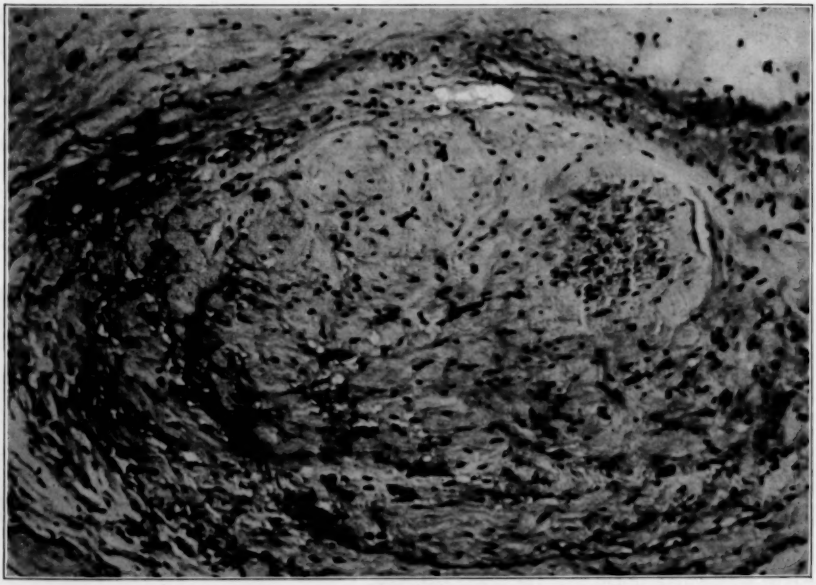

FIG. 8-C

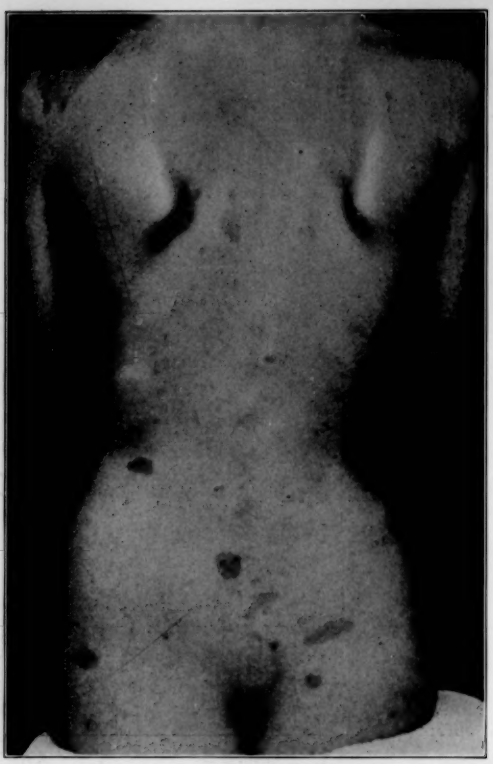

FIG. 9

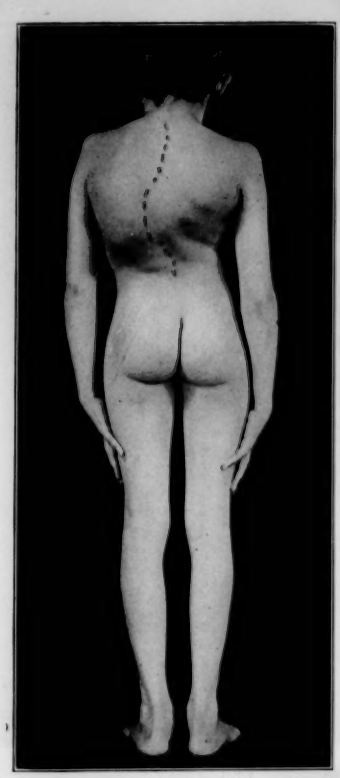

FIG. 10

Fig. 9: Mild scoliosis found during skeletal survey, conducted because of multiple *café au lait* spots. A few months later a malignant posterior-fossa tumor was found in this child.
Fig. 10: Extreme congenital scoliosis in a child who showed several *café au lait* spots.

of this series. In some instances this change was very extensive. Thannhauser, in his excellent and complete review of the subject in 1944, stated that the presence of *café au lait* spots was as much an indication of neurofibromatosis as the neurofibromatous nodule itself. The presence of a *café au lait* spot, however, is not necessarily indicative of other abnormalities, since the spots may be encountered in otherwise normal individuals. In routine examination of 100 student nurses during the past year, *café au lait* spots were found in approximately 20 per cent., without evidence of other associated abnormalities.

FIG. 11-A

FIG. 11-B

Fig. 11-A: Hypertrophy of left thumb, index finger, and corresponding portion of hand, with verrucose type of skin hypertrophy over the thenar eminence.
Fig. 11-B: Massive skeletal hypertrophy seen in the involved segments.

In several instances the *café au lait* spots made their appearance during adult life. In many others they were not noticed at birth, but appeared several years later.

In two cases a more diffuse type of unilateral increased pigment deposit was encountered, which could be classified as a true naevus lateralis. In each instance the skin was dark brown over one-half of the abdominal wall, with the change occurring exactly along the mid-line (Fig. 5-A). In one case the pigmentation was accompanied by hypertrophy of the subcutaneous tissue, skeletal changes, and primary or secondary lymphatic changes on the corresponding side (Figs. 5-B and 5-C). In the other case, the side of pigmentation showed similar changes and a diffuse hemangioma, but there were manifestations of lesser degree on the opposite side as well.

A second cutaneous manifestation occurs usually in later years, in those individuals with extremity hypertrophy involving both skeletal and soft-tissue structures. This is characterized by a rough raised verrucous or villous type of skin hypertrophy (Fig. 12-B), which presents an unmistakable appearance. The condition has been encountered in three cases, in two of which the change occurred during adult life. This manifestation had been described previously by Weiss, and seems to be characteristic of a neurofibromatous change.

Subcutaneous Manifestations

The most characteristic change in the subcutaneous tissue is the neurofibromatous nodule (Fig. 1), which was first described by von Recklinghausen. This is a true nerve-tissue tumor, usually involving a small cutaneous twig, lying in the subcutaneous tissue and invariably covered by a thin layer of areolar tissue and skin (Fig. 6). This type of involvement is rare in comparison to some of the other manifestations. It was actually proved in only three cases of this series.

The most common alteration found in the subcutaneous tissue is one of massive diffuse soft-tissue hypertrophy (Figs. 7-A to 7-D). This is usually limited to one extremity or a portion thereof, but occasionally involves two extremities, and rarely one-half of the body. In two cases of this series, the change, as described previously, was limited to two digits of a single hand (Figs. 3-A to 4-C), accompanied by some hypertrophy of corresponding skeletal structures; in each case actual hypertrophy of the corresponding nerve was demonstrated. In fifteen other cases, however, this change was not as localized (Fig. 7-A), and actual nerve hypertrophy or tumefaction was not demonstrated. The major nerve supply of these extremities has seldom been explored thoroughly, since we have felt

FIG. 11-C

Subperiosteal bone cyst in mid-portion of left radius. Note exostosis and sclerosis at proximal portion of radius, and sclerosis distally, adjacent to hypertrophied, sclerotic carpal bones.

that nothing could be accomplished by surgery of this type. In two cases in which this study was possible, no abnormality of the major nerves could be demonstrated.

There have been three cases with plexiform type of neurofibromatosis; the leg was involved in two (Figs. 8-A to 8-C) and the cheek in one. This condition is characterized by a tremendous enlargement of every nerve filament of the part; a series of tortuous cordlike tumor masses are produced, and a change results which on palpation can best be described as a mass of "fishing worms" beneath the skin. In each instance there has been some skeletal hypertrophy of the part involved (Fig. 8-B). Involvement of nerve tissues in this type of case can be easily proved at microscopic examination, as stated previously (Figs. 4-C and 8-C).

Skeletal Involvement

Actual involvement of bone structures by neurofibromatosis has long been recognized as a common manifestation of this disease. Scoliosis was the first skeletal change described, and it represents the most common abnormality of bone structures encountered in this series, having been proved in nineteen instances. In some instances it was mild and was found only after complete skeletal survey (Fig. 9). In other cases, however, it represented an extreme deformity (Fig. 10). It was frequently associated with other skeletal and clinical manifestations of neurofibromatosis. One child, twelve years of age, brought to the Clinic because of poor posture, was found to have multiple *café au lait* spots and mild scoliosis (Fig. 9). A few months later, a rapidly progressive flaccid hemiplegia developed and, after thorough neurosurgical study and exploration, the child was found to have an

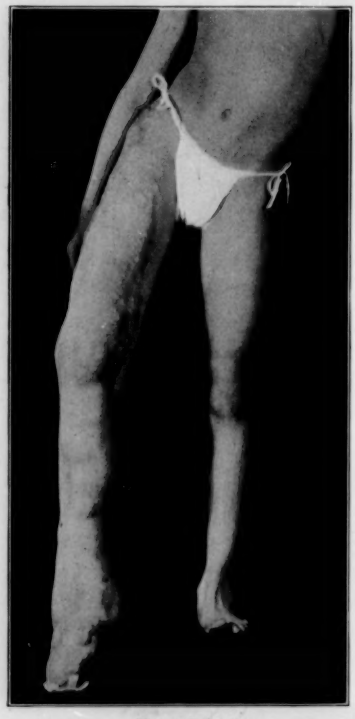

FIG. 12-A

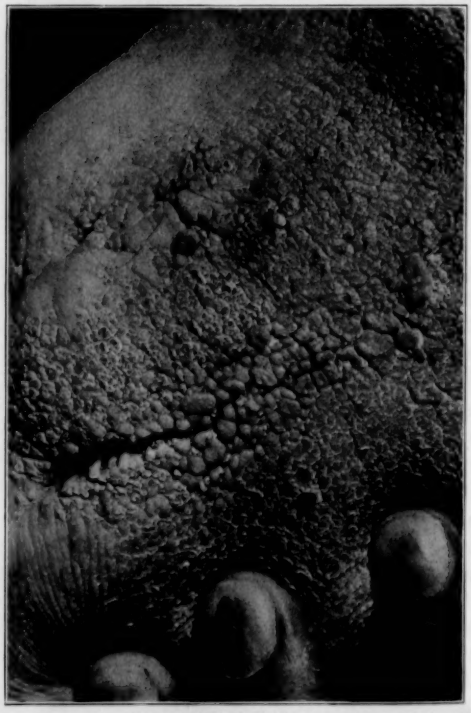

FIG. 12-B

Fig. 12-A: Tremendous skeletal and soft-tissue hypertrophy involving one lower extremity. Below-the-knee amputation was performed by LeRoy C. Abbott, M.D., when patient was twelve years of age.
Fig. 12-B: Verrucose type of skin hypertrophy was widespread over the extremity fifteen years later.

TABLE I

CLINICAL MANIFESTATIONS OF CONGENITAL NEUROFIBROMATOSIS IN FORTY-SIX CASES

Type of Involvement	Clinical Manifestations	No. of Cases
Cutaneous	*Café au lait* spots	33
	Naevus lateralis	2
	Verrucous type of skin hypertrophy	3
Subcutaneous	Neurofibromatous nodules	3
	Diffuse soft-tissue hypertrophy	17
	Plexiform type of neurofibromatosis	3
Skeletal	Scoliosis	19
	Bone hypertrophy	14
	Bone cysts	2
	Congenital shortening of lower extremity	3
	Congenital pseudarthrosis of tibia	5
	Spondylolisthesis	4
	Melorheostosis	2
Vascular	Diffuse flat hemangioma	5
	Plexiform dilatation of veins	2
	Thick-walled veins in hypertrophied subcutaneous tissue	12
Lymphatic	Oedema of hypertrophied extremity	4
	Dilated lymph spaces	3

inoperable malignant posterior-fossa tumor. While scoliosis is not an inevitable accompaniment of congenital neurofibromatosis, as was suspected by Weiss and Engman, it does occur with sufficient regularity to justify thorough investigation for other possible associated manifestations of this disease in every patient with lateral curvature of the spine.

The next skeletal changes recorded in the literature are abnormalities of growth (Figs. 8-B, 11-A, 11-B, and 12-A) and subperiosteal bone cysts (Fig. 11-C), as described by Brooks and Lehman in 1924. Abnormalities of growth may result simply in increased length (Figs. 8-A and 8-B) or an over-all hypertrophy of the involved bones (Fig. 11-B). Hypertrophy of one or both types was encountered in fourteen cases in this series. In three other cases, congenital shortening was present in one lower extremity. This occurred in conjunction with congenital absence of the fifth toe and fifth metatarsal in one patient, who also showed multiple *café au lait* spots.

Bone cysts were encountered in two patients; in one instance these were subperiosteal in type (Fig. 11-C), as described by Brooks and Lehman. This patient also had hypertrophy of the involved extremity.

Congenital pseudarthrosis of the tibia (Fig. 13-A), described in 1937 by Ducroquet and later by Barber, Moore, and Green and Rudo, was present in five patients of this group. In each instance numerous *café au lait* spots (Fig. 13-B) were present; in one there were many subcutaneous nodules and, in still another, there was a plexiform tumor mass involving one cheek. In one patient the entire area of pseudarthrosis was excised (Fig. 13-C) preliminary to the insertion of bone grafts, but no nerve tissue could be demonstrated in this area or in the cystic change of the proximal bone fragment immediately adjacent to it.

Two other skeletal changes have been encountered in this series, of which no record has been discovered in the medical literature. These changes are spondylolisthesis and

melorheostosis (Figs. 14-A and 14-B). Spondylolisthesis may occur in conjunction with a congenital defect of the pedicle of any vertebral structure and, as such, was encountered in four cases of this series. In two patients the discovery was made in conjunction with routine investigation of low-back pain; in two others the finding was accidental, in conjunction with a skeletal survey because of other manifestations of neurofibromatosis. Multiple *café au lait* spots were present in each patient. The causal relationship of neurofibromatosis to this congenital pseudarthrosis of a pedicle and subsequent spondylolisthesis has never been proved. If, however, such a disease process can result in congenital pseudarthrosis in one part of the body, as has been proved in the tibia, it would seem reasonable to assume that such a process could also result in a similar developmental change in the skeletal structures of the spine or any other portion of the body. As is true in most of these clinical findings, congenital pedicle defects and spondylolisthesis can, therefore, be listed only as possible manifestations.

Unmistakable evidence of melorheostosis has been encountered in two cases (Fig. 14-A). As stated previously, no record of the possible relationship between this change and neurofibromatosis has been found in the medical literature, although Friedman described sclerotic changes involving the pelvis and long bones which might be considered comparable or identical. That melorheostosis, a bizarre, typically unilateral, skeletal hypertrophy, or flowing hyperostosis might, in some instances at least, have its etiology in congenital neurofibromatosis was first pointed out to the author by Sherwood Moore, Professor Emeritus of Radiology at Washington University. The author is indebted to him for the first patient of this type, a woman, twenty-nine years old, who showed many *café au lait* spots and subcutaneous nodules. These nodules were proved to be neurofibromatous in type, as evidenced by the typical whorl formation (Fig. 14-E) of fibrous-tissue

FIG. 13-A

FIG. 13-B

Fig. 13-A: Extreme deformity and shortening resulting from congenital pseudarthrosis of the left tibia and fibula.

Fig. 13-B: Numerous *café au lait* spots present in this patient.

FIG. 13-C

FIG. 13-D

FIG. 13-E

Fig. 13-C: In addition to the pseudarthrosis, a cystic lesion was present in the distal end of the proximal fragment. Study of this entire excised area failed to reveal the presence of nerve tissue.

Fig. 13-D: Appearance of extremity after two-stage bone-grafting, performed by C. H. Crego, M.D. Both tibia and fibula from opposite extremity were used. Stabilization of foot was also performed.

Fig. 13-E: Appearance of tibia twenty-four months after fibular graft and eighteen months after delayed tibial graft, but prior to stabilization operation.

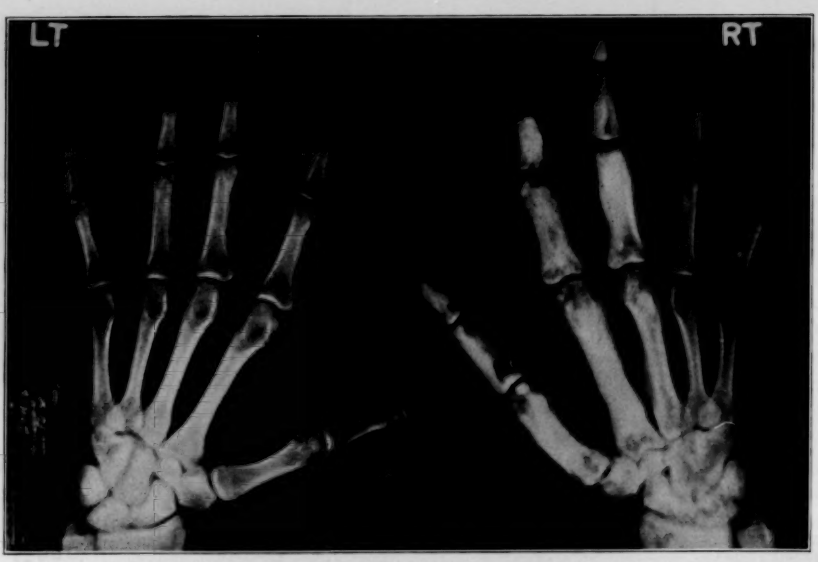

FIG. 14-A

Sclerotic changes resulting from circumferential involvement of melorheostosis in three segments on radial aspect of right hand.

FIG. 14-B

Changes typical of melorheostosis in scapula and humerus. Similar changes involved corresponding radius and radial aspect of ulna.

cells. The woman also had corresponding unilateral soft-tissue hypertrophy, scoliosis, a massive calcified ischial bursa (Fig. 14-C), and a diffuse flat hemangiomatous change involving half of the trunk and the corresponding extremities. The large calcified ischial bursa was removed, but microscopic study revealed no unusual change in the tissue. A specimen for biopsy study was taken from the involved bone of the radius, but this showed nothing except normal compact bone.

The second patient had skeletal changes compatible with melorheostosis of one lower extremity. This extremity showed increased length, circumferential hypertrophy, and one large *café au lait* spot. During the same period, one other patient with melorheostosis has been thoroughly studied and a biopsy of the involved bone has been obtained, but no other evidence could be found which would help to confirm the diagnosis of underlying neurofibromatosis. While there is strong confirmatory evidence that neurofibromatosis may possibly exist as an etiological factor in some cases of melorheostosis, its absence in other cases makes it impossible for one to consider this rela-

tionship definite, and it can only be listed as a possible clinical manifestation in this complex disease process.

Vascular Changes

A diffuse flat hemangioma has been encountered in five cases of this series in which the hemangiomatous change corresponded to the portion of the body showing soft-tissue

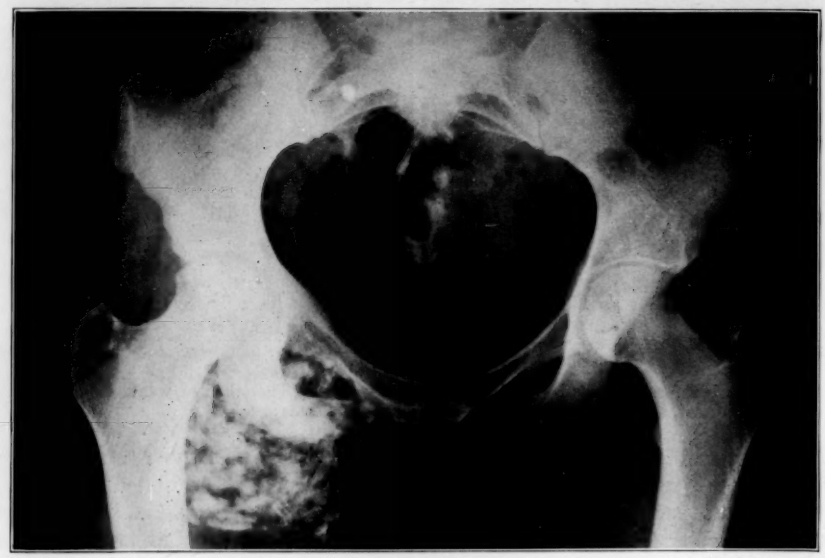

FIG. 14-C

Massive calcified tumor mass in right ischial bursa.

FIG. 14-D

After excision of tumor mass, some sclerosis could be seen in adjacent ischium, which could represent either a primary or secondary change.

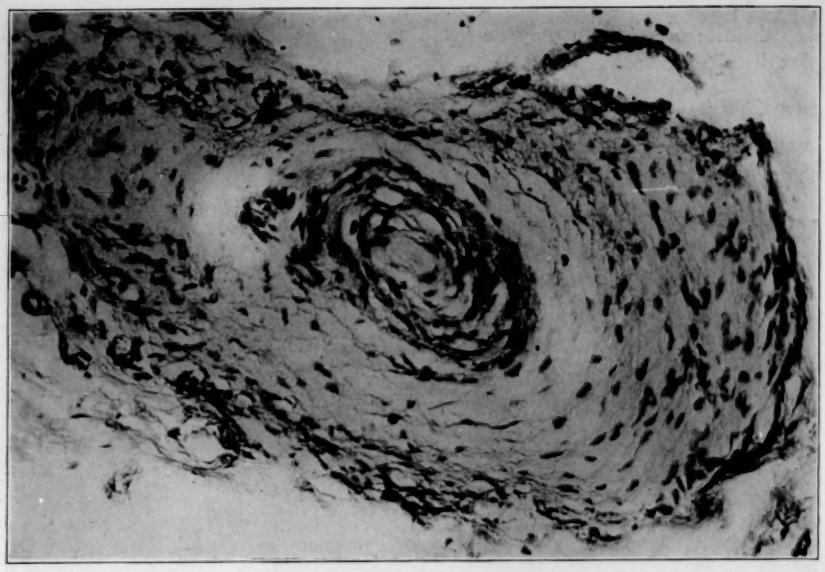

FIG. 14-E

Typical whorl formation of fibrous-tissue cells, as described by Thannhauser, was found in excised soft-tissue tumor, and was considered indicative of neurofibromatosis.

hypertrophy or other manifestations of neurofibromatosis. *Café au lait* spots were present in four of these patients. In two other cases a plexiform type of dilated veins was encountered in the subcutaneous tissue of extremities, which were explored because of soft-tissue hypertrophy. These veins were often as large as one-fourth of an inch in diameter, and considerable difficulty was encountered in maintaining hemostasis during and following the operation. In addition to these two findings, an increased number of thick-walled veins (Fig. 5-D) were encountered during microscopic study of all subcutaneous tissues removed in instances of hypertrophy of the extremities. Since these vascular alterations have been found so commonly in conjunction with the other clinical manifestations of neurofibromatosis, it again seems possible that they may be associated with the same basic developmental defect of adjacent nerve tissue.

Lymphatic Involvement

Evidence of lymphatic involvement existed in four cases of this series in the form of a tremendous oedema of the hypertrophied extremity. In three other cases, evidence of dilated lymph spaces was obvious during microscopic examination of subcutaneous tissues excised from hypertrophied extremities. This could be a primary change involving the lymphatic structures, or it could obviously be secondary to lymphatic obstruction in conjunction with the soft-tissue hypertrophy. No claim is made that this clinical manifestation is directly associated with neurofibromatosis, but the relative frequency with which it is encountered is sufficient to justify its consideration as a possibility.

SUMMARY

An attempt has been made to enumerate or describe briefly the various clinical manifestations which may be associated with congenital neurofibromatosis. In some instances the direct relationship can be proved, but in the majority of cases this has to be assumed. The frequency with which these various questionable manifestations are associated with unmistakable signs of neurofibromatosis, however, and the tissue characteristics which are found so commonly in all cases of soft-tissue hypertrophy, represent strong presump-

tive evidence that all may arise from a common etiology,—a primary developmental defect of the nervous system.

NOTE: The author wishes to express his gratitude to Sherwood Moore, M.D., and to L. V. Ackerman, M.D., for many helpful suggestions in this study, and to Mr. Kramer Lewis for the photographic work.

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DISCUSSION

DR. JOHN R. COBB, NEW YORK, N. Y.: Many surgeons are still not familiar with the importance of neurofibromatosis in orthopaedic problems, so I should like to emphasize the following points:

1. A good many cases of so-called idiopathic scoliosis are probably due to neurofibromatosis.

2. At least two forms of scoliosis may be noted in cases of neurofibromatosis. One is a mild curvature without significant tendency to rapid increase or severe deformity. The other, progressive type, may result in extreme deformities.

3. In any case where there is curvature and evidence of neurofibromatosis, the patient should be watched carefully, as this type of curvature does not follow the usual idiopathic course. Probably there are some cases which do not progress and in which fusion is not required, but where the condition is progressive, it is better to fuse early. If in doubt, fusion is safer than permitting rapid, serious progression. In all of our cases of proved neurofibromatosis with scoliosis, spine fusion was necessary.

4. Many times it is possible to make the diagnosis of neurofibromatosis merely by looking at the roentgenogram, without seeing the patient. A short, sharp, angulating scoliosis with wedging of the vertebrae in the thoracic area, especially when the opposite curve is atypical, should always be considered a potential neurofibromatosis curve until proved otherwise. Some of these cases are mistaken for congenital scoliosis with hemivertebrae, but earlier films show that the vertebral bodies were at one time apparently normal in size and shape.

5. In our experience, an adequate, massive, early spine fusion will prevent the progress of deformity, but the fusion is usually done much too late.

6. One of the worst mistakes in this type of problem results from ill-advised laminectomy when there are associated neurological findings, thought to be due to intraspinal neurofibroma. In this severe progressive type, correction in a turnbuckle jacket may relieve the neurological symptoms; spine fusion should be done *before* laminectomy is considered. If laminectomy has been done, it is extremely important to do a spine fusion as early as possible thereafter. The spinal deformity resulting from neurofibromatosis may be horrible, but laminectomy without stabilization will make it a nightmare.

DR. WILLIAM T. GREEN, BOSTON, MASSACHUSETTS: I should like, first, to commend Dr. McCarroll for a timely, interesting paper which was excellently presented.

The bizarre and varied skeletal manifestations of this disease are a continuing wonder to me. Our experience at The Children's Hospital parallels, in a general way, that of Dr. McCarroll in number of cases, in types of abnormality, and in method of treatment. We classify the skeletal manifestations somewhat differently, but that is not very important. In our cases, of which the earlier ones were the subject of an exhibit here at the Academy in 1943, the most common type of skeletal manifestation was that of localized osseous lesions of cystic appearance in the roentgenograms; scoliosis was second in frequency, and hypertrophy was

(*Continued on page 626*)

THE POSSIBLE RELATIONSHIP OF NEUROFIBROMATOSIS, CONGENITAL PSEUDARTHROSIS, AND FIBROUS DYSPLASIA

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This paper was inspired by the examination of tissue sections from fifteen cases of congenital pseudarthrosis of bone. Early in the study it became apparent that a paper concerned with this disease must of necessity include a consideration of another condition, usually designated von Recklinghausen's neurofibromatosis. Of the fifteen cases of pseudarthrosis, four had multiple nodular lesions along the course of peripheral nerves and were diagnosed neurofibromatosis; ten had well delineated, chestnut-colored areas, *café au lait* spots, of skin pigmentation. This incidence seemed high enough to suggest a more than coincidental relationship, and examination of the reports of other writers [4, 12, 19] revealed an even higher concomitance. Indeed, the relationship has become so fixed in the minds of orthopaedic specialists that the condition is quite generally designated as neurofibromatosis of bone.

Since 1860, when Kölliker described neurofibromatosis [8], a vast amount of writing has been done on the subject. Its protean manifestations have inspired the brashest speculation as to its nature and cause, until today the more cautious writer simply ascribes the various lesions to a deeply ingrained germ-plasm defect. Actually, with our present knowledge of embryology, it is impossible to explain all the deviations on the basis of a single cytogenetic mishap. Since pseudarthrosis and neurofibromatosis are unquestionably related, an explanation of this relationship becomes of therapeutic importance and probably justifies continued speculation until a more reasonable solution is hit upon.

In briefest summary, neurofibromatosis is a disease with prominent hereditary and familial features [10]. Its lesions may be regionally grouped into those of the peripheral and autonomic nervous systems, the central nervous system, the skin and subcutaneous tissues, the bones and related structures of locomotion, and, finally, the endocrine system.

Small tumors or tumor-like nodules may be produced, which Masson and Murray, Stout, and Bradley have insisted arise as proliferations of the Schwann syncytium. These are probably best called neurilemmoma, and may be of either the Antoni A or the Antoni B type. Rarely, they may undergo changes in their morphology and behavior [24] and pursue a malignant course, terminating in death. In the skin, one usually finds geographic areas of brown pigmentation. These may be macular or they may rest on a base of thickened corium to produce a plaque. Rarely the outcome may be malignant glioma of the midbrain, and at times there may be an association of all three aberrations [1]. Since the Schwann sheath, the melanoblasts, and the glial cells are supposed to be of neuro-epithelial origin, the lesions mentioned might be explained on the basis of an embryological fault in the neural crest.

So much apparently satisfies all contenders, but there are numerous other expressions of the disease. These include bizarre thickenings of the peripheral and sympathetic nerves, lipomata, sebaceous-gland hypertrophy (Pringle's disease), and pedunculated fibrous masses on the skin surfaces. Scoliosis commonly accompanies neurofibromatosis [11]; there may be pseudarthrosis and fibrous dysplasia of bone; and rarely one may find asymmetrical hypertrophy of a part, such as a finger or a whole extremity [6]. This "elephantiasis" is caused by increased bone growth and hyperplasia of the associated tissues. Thus it becomes apparent that a germ-plasm defect in an ectodermal derivative cannot, as such, explain this variety of tissue derangements.

FIG. 1-A

FIG. 1-B

Fig. 1-A: Patient with neurofibromatosis. Three types of lesions can be distinguished. The majority of the skin nodules are pedunculated masses of fibrous hyperplasia. The larger, rounded, more sessile masses, such as that over the right scapula, are lipomata. A pigmented, *café au lait* spot is seen on the left buttock.

Fig. 1-B: In a section of one of the pedunculated skin nodules illustrated in Fig. 1-A, the cells are spindled, resembling fibrocytes. The arrangement is without pattern. The overlying layer of basal cells contains an abnormal amount of melanin. Note the difference in the character of this lesion and that of the true neurilemmoma.

There is common agreement that most of this latter group of lesions involve tissues of mesenchymal origin. Some will probably disagree as to the nature of the lesions which occur along the course of peripheral nerves. Material from fourteen cases of neurofibromatosis was examined for this study. Four patients had accompanying pseudarthrosis and another had fibrous dysplasia. Thirteen had pedunculated skin masses removed for biopsy purposes (Fig. 1-A); in one the only available material was from bone. The sections from four of these thirteen cases revealed a poorly defined, subepithelial nodule of fibrosis (Fig. 1-B), or at least what looked to be fibrosis by the usual differential stains. The material from two cases showed the cytological pattern of neurilemmomata, one Antoni type A (Fig. 2) and one Antoni type B (Fig. 3). In seven cases the specimens consisted of coarse, ramifying bundles of nerve fibrils in a matrix of normal-appearing fibrous tissue (Fig. 4-A). The sections of these aggregations of nerve bundles did not resemble neurilemmoma, but rather they revealed proliferations of what appeared to be endoneural fibrocytes which surrounded and separated each nerve axon with its myelin and Schwann sheath (Fig. 4-B). In the core of the cylinder, these proliferating fibers ran parallel to the long axis of the nerve, then twisted at a right angle and ensheathed the core which contained the nerve axons, in layers of cells which ran perpendicular to the long axis of the nerve.

Thus, the pattern was remarkably similar in all seven cases in which nerve tissue was available, and the cytological picture was very different from that of the standard, recognized types of neurilemmoma. Indeed, the constancy of pattern with the central core and the surrounding sheath, the order of the cell relationships, and the variety of cell types make it exceedingly doubtful that this particular lesion of neurofibromatosis

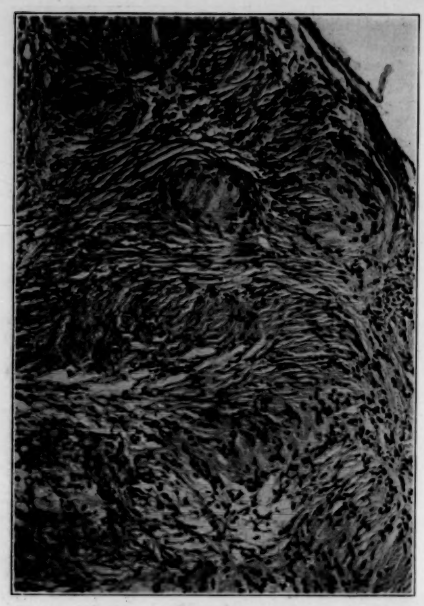

FIG. 2

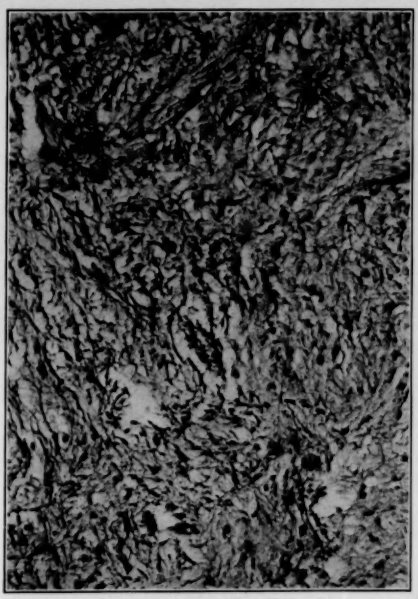

FIG. 3

Fig. 2: Photomicrograph of a section of a neurilemmoma, Antoni type A. The tumor consists of spindle cells resembling fibrocytes, which most writers now believe are derived from the sheath of Schwann. The groups of palisaded cells, Verocay bodies, characterize this tumor type.

Fig. 3: Photomicrograph of a section of tissue from a neurilemmoma, Antoni type B. This lesion is characterized by a tangled mass of plump or spindle cells with processes in an amorphous, myxomatous matrix. The A and B types are commonly mixed.

is a neoplasm. Rather, it would seem to be a hamartomatous overgrowth of a normal constituent of the nerve, the exact identity of which cannot be stated with certainty at this time. Careful examination of the material from these seven cases, however, with numerous differentiating stains, suggests that these particular proliferating cells are probably of endoneural rather than syncytial origin.

Admittedly it is impossible to be absolutely sure that the cells in question are not of Schwannian origin without culturing them, but their arrangement is so different from those of the neurilemmoma that one finds it difficult to ascribe to them the same cytogenic origin. Foot stated that neoplasms probably arise from both Schwannian and fibrous elements in peripheral nerves; the conclusions of this study are in accord. It appears, however, that the fibrous proliferations in the lesions with the bundle pattern described are less true neoplasms than hamartomata, and such is a more exact description also of the "lipomata", the sebaceous-gland aggregations, and the hypertrophied extremities which sometimes accompany them. Such also helps to explain the fibrous proliferation and metaplasia which characterize pseudarthrosis and fibrous dysplasia.

In short, one might explain the neurilemmomata, the melanomata, and the gliomata of neurofibromatosis on the basis of a germ-plasm defect involving the neural crest. We have known since the days of Cohnheim that embryologically displaced tissues and those which are genetically misformed are more apt to be the seat of neoplastic growth than normal tissues. The numerous other lesions which so frequently accompany the disease and which involve tissues of mesenchymal origin might be explained as a hamartomatous dysplasia, resulting from the altered nerve function induced by this primary germ-plasm defect. Admittedly, it has not been shown that altered impulse conduction may produce hyperplasia of related tissues, but this is a reasonable hypothesis. Recently Holt and

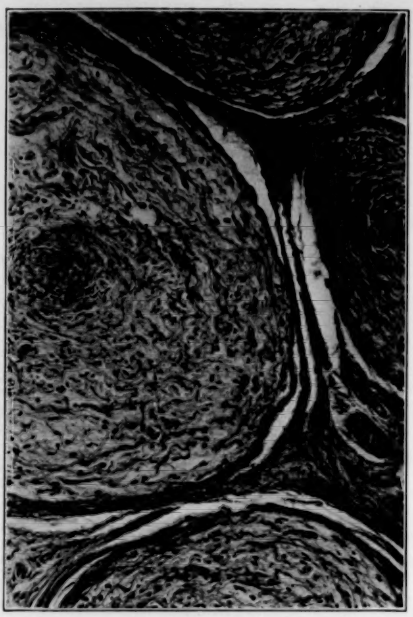

FIG. 4-A

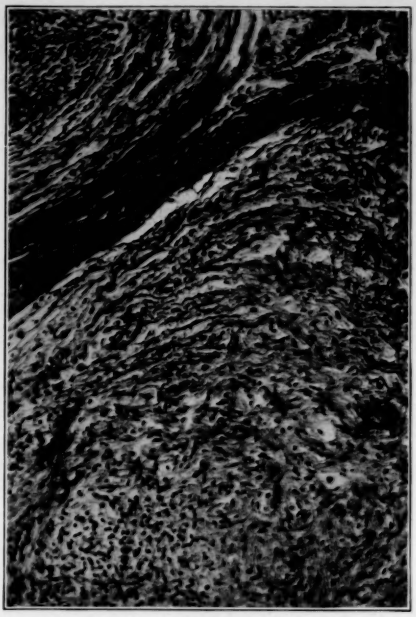

FIG. 4-B

Fig. 4-A: Photomicrograph of a cross section of one of the plexiform masses of nerves, showing the characteristic bundle pattern. Note the core of the nerve fibrils in the center of the bundle and the change in course of the ensheathing cells as they approach the periphery.

Fig. 4-B: Enlargement of the periphery of one of the nerve bundles shown in Fig. 4-A. Here, again, the cells look like fibrocytes and their arrangement is more like that of the pedunculated skin nodule of Fig. 1-B than the true neurilemmoma.

Wright, in a review of 127 cases, have also suggested the possibility of such a mechanism.

Ducroquet was the first to note the relationship of congenital pseudarthrosis and neurofibromatosis. Of his eleven cases of the former, nine apparently had some manifestation of neurofibromatosis, although actual skin nodules appear to have been present in only two. He emphasized the prominent hereditary aspect. Barber, in 1939, was the first to record the condition in the American literature. He described five patients showing bone deformity and pigmented spots, with evidence of neurofibromatosis in the immediate families. There might be a reasonable doubt as to whether his Case 2 is true pseudarthrosis. In 1943, Green and Rudo reported a case with descriptions of the microscopic findings and stated their belief, in which they have persisted, that the bone lesion was produced by a neurofibroma growing within the bone cortex; this caused fracture and interfered with union, resulting eventually in pseudarthrosis.

This seemed to the writer a reasonable explanation, and the first several cases in this series were so considered. However, in the description of the microscopic appearance of tissue submitted from these cases, there was always the statement that the arrangement of the proliferating cells (Fig. 5) was not exactly characteristic of that in either type of neurilemmoma (Figs. 2 and 3). The morphology and pattern of these cells was much more like that seen in the enlarged nerve bundles and the pedunculated masses of fibroblastic proliferation in the cases of neurofibromatosis. In a case reported by Holt and Wright, careful study of an amputated leg failed to show evidence of true tumor tissue.

As the cases were collected and knowledge grew out of a wider experience, it became apparent that there was often metaplasia of the proliferating cells into poor primitive bone and chondroid material (Fig. 6). If the lesion which causes the bone deformity of pseudarthrosis is a neurilemmoma, as Green and Rudo have contended, the participating

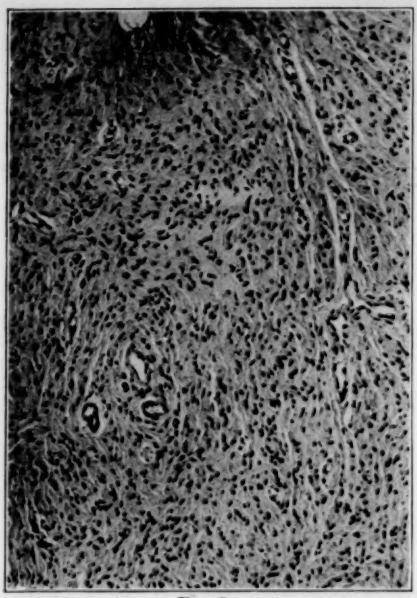

FIG. 5

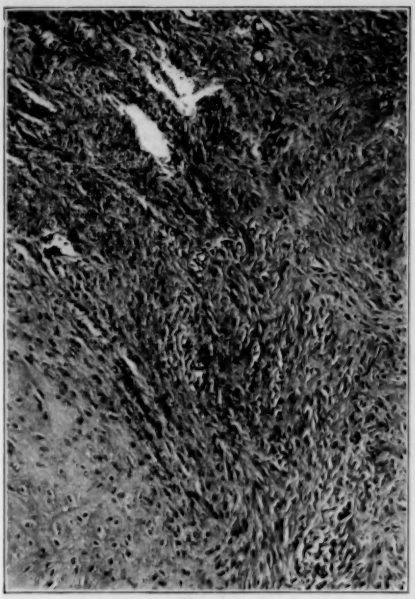

FIG. 6

Fig. 5: Photomicrograph of a section of tissue removed from the site of pseudarthrosis. There is considerable hyperplasia of cells which resemble fibrocytes. Their arrangement is not that of the neurilemmoma, as illustrated in Figs. 2 and 3, but more closely resembles that of the skin nodule of Fig. 1-B.

Fig. 6: Photomicrograph of a section of tissue taken from the site of pseudarthrosis. In the lower left corner there is recognizable chondroid tissue; in the upper right corner, fibrocytes resembling those in Fig. 5. Note the transition from one type of tissue to the other.

cells are from Schwannian syncytium and, therefore, are of neuro-epithelial origin. It is difficult at present to ascribe a neuro-epithelial origin to bone and cartilage. With this puzzle in mind, the clinical records of the fourteen cases of pseudarthrosis were examined. To ascribe the fracture and non-union of pseudarthrosis to the growth of a neurofibroma in the bone seems at first a plausible conclusion. Many of these patients have neurofibromatosis, most have *café au lait* spots which have been widely accepted as part of the stigmata of latent neurofibromatosis, and the material from the lesion is found to be a tangled mass of spindle cells which resemble those seen in the nerve and skin thickenings. Moreover, it has been shown by DeSanto and Burgess, reviewing the work of others, that nerve fibers can be demonstrated coursing through the compacta.

However, there are certain differences in clinical aspects of these cases which make this idea untenable. Congenital pseudarthrosis often begins as anterior bowing, usually of the tibia or fibula, or both. This bowing (Fig. 7) may be present at birth or it may begin early in childhood and progress over a variable period, sometimes years, until fracture occurs spontaneously or by osteoclasis in an attempt to straighten the limb. According to available roentgenographic descriptions, there is no diminution in the amount of calcium present in the bone. The bowing is apparently due to a fault in the organic constituents over a considerable portion of the shaft. This mechanism and appearance are not in accord with our concept of the manner in which tumor growth produces bone lesions. Here there is a circumscribed, focal area of demineralization which produces a pathological fracture. If the tumor is a benign one, such as an enchondroma, the fracture promptly heals and stays healed after the offending tissue has been completely removed.

In pseudarthrosis, the process is diffuse and there is an apical center which finally gives way in fracture. The lesion is not one of focal destruction of normal bone, but apparently a growth aberration with failure to produce normal bone, and a hamartomatous dysplasia

FIG. 7

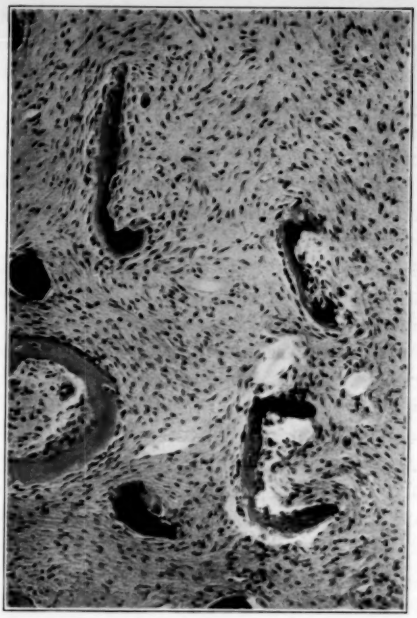

FIG. 8

Fig. 7: Roentgenogram of a tibia and fibula from a case of "congenital pseudarthrosis" in the pre-fracture stage. The bowing is characteristic. It is difficult to explain how such a lesion might result from a focal destructive bone neoplasm.

Fig. 8: Photomicrograph of a section of tissue removed from an area of fibrous dysplasia. Note the spicules of primitive bone. The interspicular spaces are filled with fibrocytes and there is apparent metaplasia of one type of tissue into the other.

to produce masses of soft tissue in an attempt to compensate for the lack of rigid substance. If the "tumor" tissue interposed between the fracture ends is completely and widely removed, there is still failure of the normal callus formation and bone healing. This is further evidence that the process is not destruction of normal bone, but rather indicates defective bone formation.

If one compares the sections of material taken from the vicinity of the fracture in pseudarthrosis (Fig. 5) with those of neurilemmoma, one cannot find great dissimilarity in any single-cell morphology, but the cell pattern often shows real differences. The interweaving of irregular trabeculae is much more like that seen in the pedunculated skin lesions (Fig. 1-B) and the thickened plexiform nerve masses (Fig. 4-B). It is this characteristic which gives rise to the suggestion that this is not a tumor, but a hyperplasia or dysplasia. The metaplasia of these connective-tissue-like cells into primitive bone and cartilage (Fig. 6) sets them apart in identity from the neurilemmoma cells (Figs. 2 and 3).

To make the issue more complex, there are well documented reports of "neurofibroma" occurring in bone. The cytological morphology and pattern in these cases is identical with that of neurilemmoma of soft parts, but the bone lesion is focal and the behavior not at all like that of pseudarthrosis. The cases reported by DeSanto and Burgess as "neurilemmoma" are unquestionably such. Examination of the photomicrographs reveals the lesions to be solitary neurilemmomata and, indeed, the authors are careful to make this distinction. In the case reported by Green and Rudo, it appears that there is indubitable pseudarthrosis, but there appears also to be a solitary neurilemmoma in the same bone. True neurilemmoma may be found in the periosteum, in which case there is usually an overlaid lamina of calcified tissue to produce the roentgenographic picture of an eccentric bone cyst. Westcott and Ackerman mentioned such cases in their report.

One of our cases showed multiple small neurilemmomata of the Antoni B type in the periosteum, very near the site of fracture.

Neurofibromatosis has been linked with fibrous dysplasia of bone by certain writers, notably Thannhauser. He emphasized the various expressions of neurofibromatosis, such as skin nodules and pigmented spots, and the endocrine manifestations which are often seen in "osteitis fibrosa cystica localisata et disseminata" (fibrous dysplasia). Jaffe forcefully took issue and brought out several differentiating features, such as the difference in the pigmented skin areas, the skeletal conformations, and the hereditary patterns of the two diseases. It is impossible and probably not very important to set down here the extent of the relationship of these two diseases. That some relationship does exist seemed quite definite when a series of nine cases of fibrous dysplasia were compared with the fifteen cases of pseudarthrosis and fourteen cases of neurofibromatosis.

When the clinical aspects of these cases were reviewed, the incidence of concomitant lesions and symptoms was greater than might be expected by comparing random population samples. This, in itself, indicates that some relationship exists, although it certainly cannot be interpreted to mean that these conditions are different manifestations of the same disease. The failure of our cases of fibrous dysplasia to show a higher incidence of pigmented skin areas is curious, since in other reported series [2, 3, 16, 17, 23, 25] these lesions are quite common. Jaffe has pointed out that only the more severe states of fibrous dysplasia are likely to be associated with evidence of neurofibromatosis. Whereas the onset of fibrous dysplasia is most often seen in the first decade and usually ceases its progressive course at skeletal maturation, neurofibromatosis is not apt to manifest itself before the second decade or later. The age limits in this series of fibrous dysplasia were two and one-half to sixteen years; those for neurofibromatosis were fifteen to seventy years, and only two patients were under twenty years. In many of the cases of fibrous dysplasia reported here, lesions of neurofibromatosis may eventually develop.

When one compares the tissue sections of fibrous dysplasia with those of the other two diseases, one feature stands out. There is metaplasia of the spindle cells, which have been interpreted by Lichtenstein as being of fibrous origin, into primitive bone (Fig. 8). These areas of metaplasia closely simulate those of the same type seen in pseudarthrosis. The arrangement of the cells between the bone spicules in both conditions is similar to that of the intercalated bundles found in the plexiform nerve lesions and pedunculated skin masses of neurofibromatosis, and less like the pattern seen in neurilemmoma.

When the cases of these three series were compared, the following conclusions were suggested:

1. The overlapping in the clinical signs and symptoms and the similarity in cell morphology and pattern strongly suggest that these three conditions are in some way related.

2. In neurofibromatosis there are both true neoplasms (neurilemmoma, melanoma, and glioma) and hamartomatous proliferations (the bundle-pattern lesions described here). The lesion of pseudarthrosis appears to represent an inability in certain areas to form a normal organic matrix. The shoddy bone undergoes fracture and there is an inability to produce healthy callus. Instead there is a hamartomatous proliferation of fibrous tissue (leading some to mistake it for "neurofibroma"), which undergoes metaplasia into poor and disorganized bone. The lesion of fibrous dysplasia, like pseudarthrosis, represents an inability to produce normal bone in one or more areas with metaplasia of the fibrous tissue into primitive bone.

3. The fibrous proliferations of the latter two conditions are unlike the true tumors of neurofibromatosis, but quite similar to the hamartomatous structures of that disease. It is suggested that these curious fibroblastic masses have a common cause in all three conditions,—that is, an alteration in the nerve pathways which produce abnormal growth and maturation of the tissues supplied. The studies of B. H. Moore corroborate this theory to some degree.

These conclusions would be of little more than academic importance unless their principles could be applied in therapy. Such has been done in a series of eight cases by J. R. Moore[21]. Reasoning that the lesion was not simply an area of bone destruction by focal tumor, but rather an inability to produce bone, he attempted to bring in a set of normal osteoblasts from an uninvolved area. Delayed bone-grafting was done by carving out the graft to be used and allowing it to remain in its native site until new-bone formation had begun on the dead bone of the graft. By delaying the transportation of the graft, it was hoped that new and healthy osteoblasts would be carried to the site of pseudarthrosis.

Sections prepared from the bone graft at the time of preparation and again at the time of removal appeared to corroborate this idea. The results of this method of treatment seem, at present at least, to be considerably better than those of the older methods.

This would appear to be a reasonable method of treatment of the early and focal lesions of fibrous dysplasia. If the involved areas could be excised and healthy osteoblasts could be imported, perhaps enough strong bone could be produced at the site to prevent the hideous deformities which accompany the disease. Repeated operations would be necessary as the lesions develop, until the period of skeletal maturation.

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DISCUSSION

Clinical Manifestations of Congenital Neurofibromatosis

(*Continued from page 617*)

third. The tibia was most commonly involved, and in this bone the manifestation was in one or more of four forms: a sinuous bowing, overgrowth, local defect, and pseudarthrosis. In our experience, pseudarthrosis of the tibia in childhood has been associated with neurofibromatosis, with possibly one exception. The manifestation of sinuous bowing of the tibia should be emphasized, since it is a characteristic lesion.

The real problem, and the subject of our interest, is: Why do such bizarre skeletal manifestations occur? In certain instances they are due to the presence of local neurofibromata, but in others the relation is obscure. Neurofibroma is thought by most individuals to arise from ectoderm, to have its origin in the Schwann cell, and to be in reality a sarcolemmoma. There are, however, supporters of the idea that it arises from the perineural cells and is of mesodermal origin. If it is of mesodermal origin, the relation of the skeletal abnormalities is more direct; but if, as appears much more likely, neurofibroma is of ectodermal origin, explanation of the skeletal manifestations is difficult. The question arises as to whether the normality or abnormality of nerve tissue influences the development of structures of mesenchymal origin. In some of the simpler animals, this is true. Or, instead, does the high incidence of osseous lesions in neurofibromatosis indicate that the same influence in embryologic life produces anomalous development of structures of both ectodermal and mesodermal origin? Another perplexing question arises regarding the possible relation of neurofibromatosis to Albright's syndrome or fibrous dysplasia. *Café au lait* spots are features of both, although the bone lesions in their detail show different characteristics.

We started out to answer some of these questions but, unfortunately, our answers are still too few. Dr. McCarroll has not answered these questions, either. At any rate, this is a field for investigation upon which hinges much more than the manifestations of neurofibromatosis.

Dr. H. R. McCarroll (closing): I appreciate very much the kind discussion. I can only state that I knew more about neurofibromatosis a year ago than I know today. Those of you who are interested in this problem will find that it has unlimited possibilities and too many ramifications to mention. The further you get into it the more complicated it seems.

We have not attempted to answer any questions. We have simply tried to show the problems encountered and what we believe are manifestations of this disease process, in the hope that we may stimulate interest in this field.

AN ANALYSIS OF PARALYTIC THUMB DEFORMITIES

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From Georgia Warm Springs Foundation

Paralysis of the opposition unit of the thumb is a major disability. The degree of deformity depends primarily upon the anterior-horn cells affected, and the treatment hinges upon the resulting deformity. Furthermore, the status of the thumb is not constant, and the secondary changes which occur in bones, joints, and soft tissues make an ideal end result difficult. The factors of nerve supply, muscle strength, joint contractures, joint stability, and vascular status must all be considered. The interval from onset of disease, the occupation, the general physical condition, and the stability of the remainder of the arm and forearm must be evaluated before reconstruction is attempted. The treatment of each thumb will vary according to the pathological changes present. With these facts in mind, a general classification will be outlined, and the variations in treatment will be discussed.

EARLY TREATMENT

Children

The child with weakness of the hand following destruction of motor cells in the cord must be treated in preparation for the future. Even while routine care and muscle re-education are being carried out, the patient is fitted with a splint to hold the thumb in

FIG. 1-A

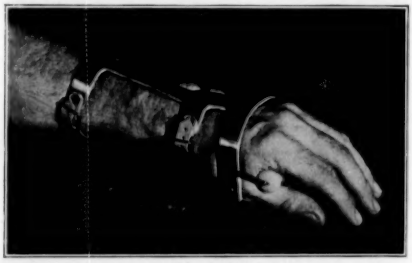

FIG. 1-B

Splints used for weakness of opposition.

Fig. 1-A: The plexiglas splint holds the thumb in abduction; it will not control a thumb with contractures. It is used best by adults.

Fig. 1-B: Basic aluminum splint with wrist attachment. This is worn prior to operation to prevent contractures and to increase function. It is used postoperatively to protect transplanted tendons. This splint is more durable for children than the plastic kind. It helps prevent joint subluxation, joint contractures, and faulty habits. Adjustment should be made every few months for children, since the child will discard the splint if it does not fit properly.

the position of function (Figs. 1-A and 1-B). A proper selection of splint is necessary. If the deformity is already severe or the hand is rigid, a plastic splint will not hold the metacarpal in position. Then the metal splint, with or without wrist attachment, may be necessary (Fig. 1-B). Home care, particularly in the form of stretching and diversional therapy, should be given.

The time for any operative procedure on the tendons of the hand will depend upon the size and, to some extent, upon the intelligence of the patient. In general, it is wise to wait until the bone structure is fairly mature and until the child can actively participate in muscle re-education. The minimum age is about twelve to fourteen years.

* Aided by a fellowship from the National Foundation for Infantile Paralysis, Inc., New York, N. Y.

Adults

The principle of maintaining a full range of motion in and about the thumb applies for adults as well as for children. Splinting in the position of function, stretching, and resistance exercises for increase in muscle strength and coordination should be pursued actively before surgery is considered.

CLASSIFICATION AND SURGICAL TREATMENT

The one factor common to all the hands to be considered is partial or complete loss of the function of true opposition. There are variations in degree from almost unnoticeable deformity to the completely useless hand. To be in true opposition, the thumb must be opposite the fingers, with the pulp of the thumb facing the radial pulp of the fingers and the thumb nail almost parallel with the palm. Merely touching the fingers or palm with the thumb is not opposition. This is "false" opposition, or apposition. The thumb must abduct, pronate, and flex for opposition.

A classification based on the treatment necessary for the best end result will be presented. This classification emphasizes the fact that a single procedure, or even a combination of procedures, cannot be stereotyped for any weak thumb.

Group I. Thumb Requiring only Transplantation of the Flexor Digitorum Sublimis

Transplantation of the flexor digitorum sublimis of the ring finger to the proximal phalanx of the thumb is the most physiological method and, in general, gives the best result in cases of uncomplicated opponens weakness. It fulfills the principles established by Bunnell in that (1) the tendon passes subcutaneously from its insertion in the direction of the pisiform bone, and (2) a transplanted tendon is inserted on the dorsal ulnar aspect of the proximal phalanx of the thumb.

Many prerequisites are necessary for an excellent postoperative result; their absence will cause the results to be unsatisfactory. These prerequisites are:

1. A strong flexor pollicis longus.
2. A strong extensor pollicis longus and abductor pollicis longus.
3. A good or better flexor digitorum sublimis of one of the fingers, preferably the ring finger.
4. A good or better flexor carpi ulnaris, for use as a pulley.
5. No bone, joint, or soft-tissue deformity present about the thumb.
6. Good strength in the fingers and a good palmar arch.
7. Adequate coordination and minimal tremor.

A. *Usual Deformity*

Figures 2-A and 2-B show the usual deformity in a hand from which an excellent postoperative result can be expected. There is weakness and atrophy of the intrinsic thenar muscles, but good strength in the extrinsic muscles. There are no contractures of the thumb unit, and the remainder of the hand is strong (Fig. 2-A). "False" opposition, however (Fig. 2-B), is the result of weak intrinsic thumb muscles. The first metacarpal bone cannot be elevated. The flexor pollicis longus and adductor pollicis pull the thumb across the palm and the entire effort of the hand is used, as can be seen by flexion at the interphalangeal joints of all the fingers. The easier the action of opposition, the less "forced" is the appearance of the remainder of the hand.

B. *Treatment*

Treatment consists in keeping the entire hand well stretched, using an opponens splint, and regaining all possible strength and coordination. Then the flexor digitorum sublimis of the ring finger should be transplanted (Figs. 2-C and 2-D). The flexor carpi

ulnaris pulley must be strong, to prevent radial deviation of the hand and wrist and stretching of the transplant. Following this procedure, the intrinsic muscles have been replaced by the tendon of the sublimis and its muscle motor. Figures 3-A, 3-B, 3-C, and 3-D show the operative technique used in the sublimis transplantation.

The ease with which true opposition may be performed after operation is indicated by the coordinated action of the first four fingers and the elevation of the fifth finger (Fig. 2-D).

Group II. Thumb Requiring Reinforcement of Its Extrinsic Strength before the Flexor Digitorum Sublimis Can Be Transplanted

A. *Usual Deformity*

In this group the intrinsic muscles are weak. The over-all strength of the palm and fingers is good; coordination is good; there are no soft-tissue contractures or bone deformities. One extrinsic muscle, for example, the extensor pollicis longus, rates "fair minus" (40 per cent.). If the flexor sublimis transplantation is done without adding strength to the weak long extensor, the result will not be satisfactory. This thumb is

FIG. 2-A

FIG. 2-B

Group I

Fig. 2-A: The extrinsic muscles allow a good pinch between the thumb and index finger.

Fig. 2-B: "False" opposition. The thumb cannot be abducted or pronated. Extreme effort is evident in attempting opposition. There are no contractures and there is good strength in the hand, except for the thenar group. The palmaris longus, flexor pollicis brevis, and flexor carpi radialis all are being used for substitution. The pinch between the thumb and little finger is at least 50 per cent. less than between the thumb and index finger, and the thumb tends to roll into an external position when the patient tries to pinch against slight resistance.

FIG. 2-C

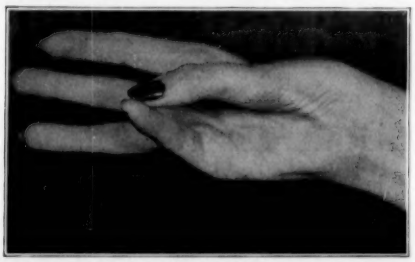

FIG. 2-D

Fig. 2-C: After operation, the thumb can be abducted. The flexor digitorum sublimis goes under the flexor carpi ulnaris, the pulley at the wrist, and is inserted on the dorsal ulnar aspect of the proximal phalanx of the thumb, to the volar side of the metacarpophalangeal joint.

Fig. 2-D: True opposition is now possible without effort. Patient has full functional capacity and excellent strength. Note the abduction, pronation, and flexion of the thumb. A cast was used for one week after operation, followed by a splint for four weeks. (Compare with Fig. 2-B.)

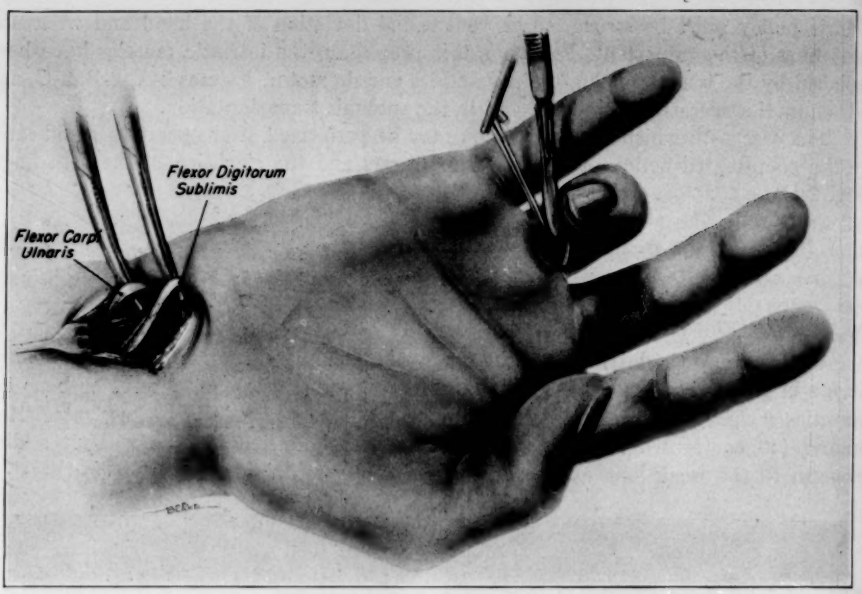

FIG. 3-A

Technique of using the flexor digitorum sublimis for an opponens transplant.

Fig. 3-A: The slips of the flexor digitorum sublimis are isolated at the volar crease of the metacarpophalangeal joint of the ring finger. The flexor carpi ulnaris is isolated for the pulley, and the sublimis is pulled out at the wrist.

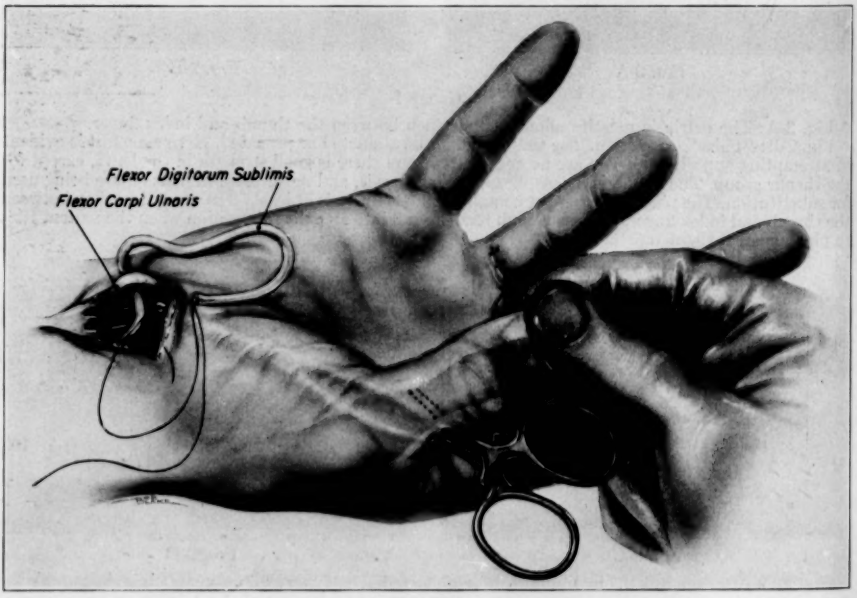

FIG. 3-B

The flexor digitorum sublimis is passed under, then over, the flexor carpi ulnaris. A subcutaneous tunnel is made from the dorso-ulnar side of the proximal phalanx of the thumb to the wrist incision. The thumb is held in abduction and full rotation.

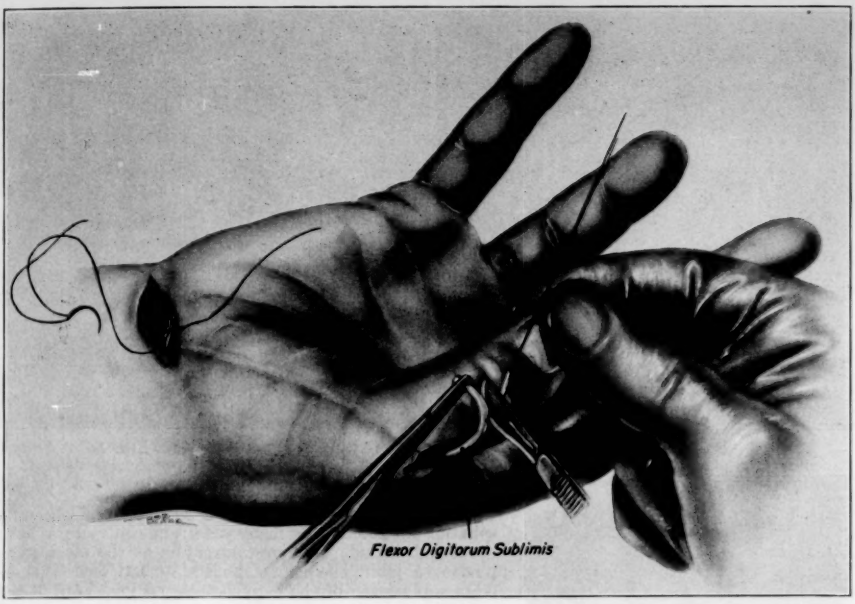

FIG. 3-C

The transplanted tendon is now in its new location. It is split into two segments; one will be anchored in bone and the other in periosteum. The wrist is flexed and the thumb is held in opposition.

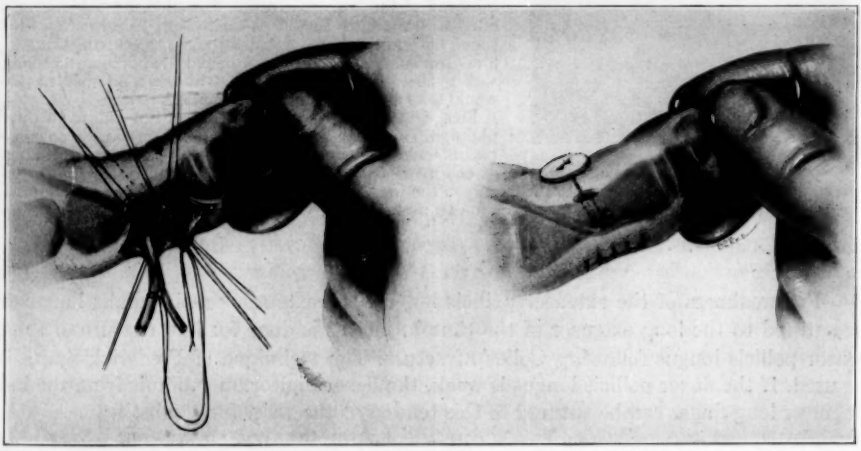

FIG. 3-D

A drill hole, about one-eighth of an inch in diameter, is made in the proximal phalanx, being directed toward the pisiform bone. A piece of medium silk is looped over one segment of the tendon, and tension is made with a hemostat on the other. A needle is passed through the drill hole; one silk loop with the tendon in it follows, the tendon being allowed to double on itself. When the doubled tendon is passed entirely through the hole, the tendon is secure and the thumb stays in the position of opposition. A button is used to anchor the silk. The second segment of tendon is sutured to the periosteum for additional support. The wrist is immobilized in flexion and ulnar deviation to keep the transplant under tension.

similar in appearance to that in Group I. If the routine muscle test is not done, the weakness of the long extensor may be overlooked.

FIG. 4-A FIG. 4-B FIG. 4-C

FIG. 4-D

Group III

Fig. 4-A: The thenar muscles are weak; there has been no splinting or stretching for many years; and contractures have developed, including flexion-contracture at the metacarpophalangeal joint. The palm is moderately flat. There is moderate subluxation of the carpometacarpal joint toward the volar side.

Fig. 4-B: In extension, the thumb has a typical "cocked-back" appearance. The skin and fascia between the first and second metacarpals are contracted, as is the adductor pollicis and its fascia. The dorsal capsule of the carpometacarpal joint is contracted. Three years before, in the presence of these deformities, the sublimis tendon was transplanted to the head of the first metacarpal. Function did not improve. Surgical procedures should be carried out to correct all soft-tissue deformities and joint deformities, after which a sublimis transplantation to the proximal phalanx can be done. A synostosis between the first and second metacarpals would take away too much motion and strength.

Figs. 4-C and 4-D: From the muscle test and from these photographs, it would seem that a flexor sublimis transplantation could be done. There is, however, flexion contracture at the metacarpophalangeal joint. Not until this joint contracture, as well as the skin contracture between the first and second metacarpals, has been corrected, can a good result be expected following tendon transplantation.

B. Treatment

For weakness of the extensor pollicis longus, the extensor carpi radialis longus can be sutured to the long extensor of the thumb, just as is done for late rupture of the extensor pollicis longus following Colles's fracture. The technique of Frederick Smith can be used. If the flexor pollicis longus is weak, the flexor digitorum sublimis from the index finger or long finger can be sutured to this tendon at the wrist for a substitute.

Group III. Thumb Requiring Release of Contractures Followed by Transplantation of the Flexor Digitorum Sublimis

A. *Usual Deformity*

This group, for the most part, comprises thumbs which have been weak in the function of opposition for many years. There has been no splinting, no stretching, and no attempt to maintain joints with a full range of motion or soft tissues without contractures. A typical thumb can be described as having a "cocked-back" appearance; the individual deformities causing this are many (Figs. 4-A to 5-B).

The adduction deformity is the result of an adduction contracture plus the action

FIG. 5-A

FIG. 5-B

Group IV

Fig. 5-A: Before operation, the carpometacarpal joint is relaxed and hypermobile, and the extrinsic muscle strength is only 50 per cent. It is necessary to stabilize this joint.

Fig. 5-B: The palmaris longus has been transplanted to the flexor carpi ulnaris and the carpometacarpal joint has been fused. The flexor digitorum sublimis has been transplanted to the proximal phalanx of the thumb. The metacarpal is fused in abduction and pronation. Function and appearance are improved.

of the long and short extensor tendons against the weak intrinsic muscles, causing the metacarpal to be adducted and externally rotated. Subluxation or contracture of the carpometacarpal joint follows when the thumb lies at the side of the hand continually in the position of external rotation and adduction, or when the patient is doing much crutch walking or resting on the hand while sitting. The capsule on the volar side of the carpometacarpal joint stretches and relaxes, and the ligaments on the dorsum shorten and contract (Figs. 4-A and 4-B); or the whole unit of the greater multangular and the metacarpal may be partially relaxed and hypermobile in all directions (Fig. 5-A). Flexion contracture at the metacarpophalangeal joint results from tight adductors and frequent use of the hand in "false" opposition (Fig. 4-C), leading to contracture of the collateral ligaments and the capsule at this joint (Figs. 4-A and 4-B). When the patient attempts to extend the thumb (Fig. 4-D), the unit as a whole moves into extension, but the metacarpophalangeal joint remains flexed. This fixed flexion contracture may measure 45 degrees.

B. *Corrective Procedures*

With a metal thumb splint, the metacarpal is elevated and held in enough abduction to allow for a stronger pinch between the thumb and fingers. A better grasp of large and small objects is accomplished by use of this splint. A plastic splint, however, will not aid this patient, for it will not hold the metacarpal in abduction. Neither splint will add much to the action of rotation. If the splint improves function, the correct surgical procedures should do the same.

If, however, a sublimis transplantation is done on the hand shown in Figures 4-A and 4-B with the expectation of improvement in function or appearance, the patient and the operator will be disappointed. The thumb already has fixed deformities. Inserting a tendon into the proximal phalanx will tend to increase the flexion contracture at the metacarpophalangeal joint. A sublimis transplantation will not allow abduction, because of the skin and fascial contractures between the first and second metacarpals. If the sublimis is inserted into the distal end of the metacarpal, "false" opposition will still be present. There may be slight improvement in the depth of the carpal arch; but, because of the existing contractures, there will not be true opposition. This is seen in Figures 4-A and 4-B; in this patient a sublimis transplantation to the distal end of the first metacarpal has already been done, the flexor carpi ulnaris being used as a pulley. On examination the transplant can be felt and seen to move.

Since the muscle test shows good extrinsic muscles, the following procedures may be done:

1. A partial capsulotomy at the metacarpophalangeal joint.

2. An L-plasty or Z-plasty of the skin on the dorsum of the hand between the first and second metacarpals, to remove the skin contractures.

3. Cutting of the fascia between the first and second metacarpals and stripping the periosteum from the first metacarpal, if necessary, to loosen the contracture between the metacarpals. Stripping of the adductors from the first and third metacarpals may also be done.

4. A capsulotomy of the carpometacarpal joint on the dorsum, and placing the metacarpal in the proper position to correct the contracture at this joint.

5. Following these procedures, which can all be done at one operation, the thumb can be immobilized in a snug-fitting plaster cast for three weeks in the position of abduction and pronation opposite the long finger. After the plaster has been removed, a metal opponens splint can be applied with a rubber-band cuff for rotation. Joint motion will be restored. If the carpometacarpal joint remains reasonably stable and the contractures are eliminated, the sublimis can be transplanted to the proximal phalanx of the thumb. If the carpometacarpal joint is hypermobile, but the strength of the extrinsic thumb muscles and the remainder of the hand is excellent, a sublimis transplanation will give enough support to allow stable action of this joint. Fusion of the carpometacarpal joint should be avoided unless the contractures cannot be eliminated or there is extreme hypermobility. Synostosis between the first and second metacarpals should not be done in this type of hand, because it takes away too much motion and strength. If synostosis is done, it is desirable that pseudarthrosis develop, so that the available muscle power will be utilized fully.

FIG. 6

Group IV. There is hypermobility at the carpometacarpal and metacarpophalangeal joints. Muscle strength of the entire hand is only 50 per cent. The thumb has a "cocked-back" appearance because of weakness, but not because of contractures.

Group IV. Thumb Requiring Correction of Joint Hypermobility with or without the Release of Joint and Skin Contractures, Followed by Transplantation of the Flexor Digitorum Sublimis

A. *Usual Deformity*

In this group the thumb is a weak unit of a fair hand. The muscle strength of the hand in general would rate only "fair plus" (60 per cent.). Several deformities must be considered and corrected.

1. *Hypermobility of the carpometacarpal joint* with instability at the joint, relaxed collateral ligaments, and a stretched joint capsule constitute the main deformity. The metacarpal bone is externally rotated while at rest; it stands out clearly because of thenar atrophy and flattening of the palm (Figs. 5-A and 7-A).

2. *Adduction of the thumb* is also present, although in Figure 5-A the skin and fascia are not particularly tight, whereas in Figure 7-A the dorsal skin and fascia are contracted.

3. *Hypermobility at the metacarpophalangeal joint* may be present. The metacarpophalangeal joint is relaxed, and it buckles when the patient attempts to pinch. It is hypermobile in all directions.

4. *Wrist weakness* may be present. This will require that the flexor carpi ulnaris be reinforced before it can be used as a pulley.

FIG. 7-A

FIG. 7-B

Group IV

Fig. 7-A: The palm is flat and there is partial subluxation of the carpometacarpal joint of the thumb on the volar side. There is a contracture of the carpometacarpal joint on the dorsum. The abductor of the little finger is weak. The fifth metacarpal cannot be elevated.

Fig. 7-B: Transplantation of the flexor digitorum sublimis to the proximal phalanx of the thumb had already been done, but the end result was not satisfactory. There is still adduction and external-rotation deformity. Tendon transplantation will not correct joint deformity.

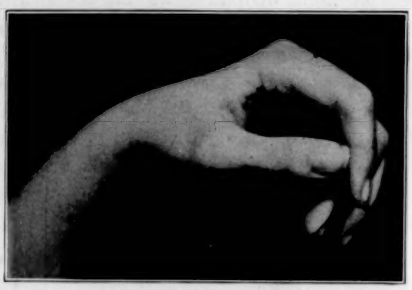

FIG. 7-C

FIG. 7-D

Fig. 7-C: Contracture on the dorsum of the carpometacarpal joint has been released and this joint has been fused. The transplanted tendon can now function, since the thumb is abducted.

Fig. 7-D: There is good pinch between the thumb and index finger. More motion is possible between the first and second metacarpals than if a synostosis had been done.

B. *Corrective Procedures*

1. The first procedure is *transplantation of the palmaris longus,* near the insertion of the flexor carpi ulnaris, into the pisiform bone. This can be used as an ulnar flexor as well as an active pulley for the sublimis transplant.

2. Next the *greater multangular is fused to the base of the first metacarpal* to eliminate all instability and motion at this joint. A moderate amount of flexion and extension still remain in the intercarpal joints, and pronation is still present at the first metacarpophalangeal joint after fusion at the base of the thumb. Following the tendon transplantation and joint fusion, the thumb is immobilized in a snug cast in the functional position. At four weeks the cast can be removed, and joint motion restored, in preparation for the second operation.

3. *Two small Kirschner wires are inserted between the first and second metacarpals.* These wires allow full mobilization following tendon transplantation.

4. A *flexor sublimis transplantation* is then done, and active motion is started in one week.

C. *Improvement in Function*

With the carpometacarpal joint fused, the transplanted sublimis will assist only in pronation and will augment the flexor pollicis longus in flexion. Clinically the trans-

planted tendon can be palpated when undergoing active motion. This transplant has only 35 to 50 per cent. of the strength of those in which the carpometacarpal joint is freely movable (Figs. 5-B and 7-C).

Although this procedure is followed by limitation of motion, it appears to be better than formation of a synostosis between the first and second metacarpals; with the synostosis, the carpometacarpal joint is still hypermobile and the entire thumb frequently falls back into external rotation, because the pre-existing deformity of subluxation has not been corrected.

D. *Hypermobility at the Metacarpophalangeal Joint*

In hands with true hypermobility at the metacarpophalangeal joint, the thumb "cocks back" (Fig. 6), but there is no contracture, as is seen in Figures 4-A and 4-B. The usual external rotation and adduction deformity is present, and the hand in general is weak, although the first metacarpal can be elevated. Surgical procedures on this hand will not increase function appreciably.

E. *Complete Obliteration of the Carpal Arch*

In the case exhibiting this deformity, the carpal arch, instead of having a concave contour, was convex (Fig. 7-A). The palm was flat, and this gave the appearance of a

FIG. 8-A

FIG. 8-B

FIG. 8-C

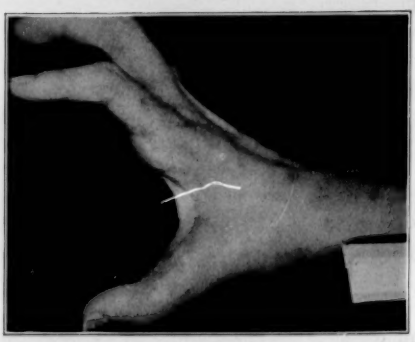

FIG. 8-D

Group VI

Fig. 8-A: In the preoperative photograph, there is weakness of the first dorsal interosseus as well as of the thenar muscles. Shows position assumed when opposition is attempted. The flexors of the index finger and the thumb are used for the pinch.

► Figs. 8-B, 8-C, and 8-D: Postoperative result. The extensor indicis proprius has been prolonged with a graft of fascia lata, and has been transplanted to the first interosseus insertion and dorsal aponeurosis. The flexor digitorum sublimis has been transplanted to the proximal phalanx of the thumb. Full abduction and opposition of the thumb are possible. Abduction against resistance and extension of the interphalangeal joints to 180 degrees are evident in the index finger. The hand has excellent function.

true "ape hand". There was relaxation of the carpometacarpal joint, external rotation and adduction, and contracture of the skin, as well as moderate relaxation of the metacarpophalangeal joints as a group. The intrinsic and extrinsic muscles of the hand had only 50 per cent. strength. A sublimis transplantation had already been done (Fig. 7-B), and the poor result was evident. Following the transplantation, the proximal phalanx was pulled slowly into flexion and the metacarpal dropped back into external rotation and adduction.

Fusion of the carpometacarpal joint was done, which stabilized the thumb in the position of abduction and helped restore some concavity to the carpal arch (Figs. 7-C and 7-D). The sublimis transplant then augmented the flexor pollicis longus and added pronation at the metacarpophalangeal joint.

Group V. Thumb Requiring Synostosis between the First and Second Metacarpals or Fusion of the First Carpometacarpal Joint without Tendon Transplantation

With a general strength in the hand of only "poor" or "poor plus" (20 per cent.), reconstructive surgery will not accomplish much. Thumb surgery for cosmetic reasons only is usually not indicated, but occasionally it may be necessary.

If the synostosis is done in the hand with "fair" to "fair plus" (50 per cent.) strength, the development of pseudarthrosis results in better function than if rigid union had taken place between the first and second metacarpals. This indicates that, if adequate functional strength is evident in the initial evaluation of the hand, synostosis is not the procedure of choice. Fusion of the carpometacarpal joint will allow more mobility and probably greater stability.

In general, formation of a synostosis between the first and second metacarpals is done too often merely because of the presence of an adducted, externally rotated thumb. This operation should be used only on the weakest hands and those which have very little function. Frequently, it takes away whatever adaptation the patient has already made.

Group VI. Group in which Miscellaneous Procedures on Parts of the Hand Other than the Thumb Are Desirable before a Sublimis Transplantation is Done

A. *Limitation of Function*

When the first dorsal interosseus muscle is weak, abduction and extension of the index finger are not possible. If opposition is weak also, an attempt to make a circle with the thumb and index finger gives the position seen in Figure 8-A. In the case illustrated, there were no joint contractures, and no contractures of the skin or soft tissue. The general strength of the hand was good.

B. *Corrective Procedures*

The extensor indicis proprius tendon was reinserted, toward the dorsoradial side of the proximal phalanx of the index finger, into the interosseus tendon and dorsal aponeurosis. A sublimis transplant to the proximal phalanx of the thumb, the flexor carpi ulnaris being used as a pulley, was applied four weeks later. Figures 8-B, 8-C, and 8-D show the postoperative result.

If the flexor carpi ulnaris is weak, the palmaris longus can be sutured to the flexor ulnaris near its insertion into the pisiform; four weeks later the sublimis can be transplanted around these tendons. If the finger extensors are of fair strength, one of the wrist tendons may be inserted into the common extensor tendons. If the finger flexors are weak, the problem is more difficult, since the other muscles in the hand are usually weak, also.

POSTOPERATIVE CARE

A brief outline of the postoperative care will be presented:

1. A light cast should be applied, with the wrist in moderate flexion and ulnar devia-

tion. The thumb should be placed in the position of full abduction and full rotation, opposite the long finger, with the transplant under the proper amount of tension, the fingers being left out to permit active exercise. As soon as the patient awakens from the anaesthesia, he is instructed to attempt active motion. He can feel the tendon move, even though the thumb is immobilized in plaster.

2. The metal splint (Fig. 1-B) is applied one week after operation, with a wrist attachment and an extension to the proximal phalanx of the thumb if necessary. Tape slings or light elastic traction on the thumb can be used in certain cases. Daily instructions are given to the patient by the surgeon. These vary, depending upon the postoperative condition of the thumb.

3. Occupational and diversional therapy are started soon after the plaster has been removed. Crutch walking is not allowed for a few weeks, and the patient is taught to support himself in ways which do not require use of the palm of the hand; otherwise, the transplant will be stretched.

4. The button and the silk suture are cut in four weeks.

STATISTICAL DATA

This study is based on an analysis of the end results in ninety-one thumbs operated upon in this Clinic during the past ten years. There were seventy-nine patients in the group; twelve had bilateral deformity of the thumb.

Transplantation of the flexor digitorium sublimis from the ring finger was done in seventy-three cases. The results were excellent in fifty-nine of the seventy-three, in which only the flexor digitorum sublimis was used as the motor. In the remaining fourteen cases, the results were fair to poor for the following reasons:

1. Technique not adapted for deformity (insufficient extrinsic muscle power about the thumb) in six patients.

2. Faulty surgical technique (tendon placed under insufficient tension) in four cases.

3. Tendon pulled loose from its attachment in the thumb phalanx in one patient.

4. The presence of adduction contracture about the thumb (the contracture was not overcome prior to transplantation) in three patients.

The remaining eighteen thumbs of the total of ninety-one were treated by miscellaneous operative procedures, as follows:

1. A sublimis transplantation to the thumb, supplemented by redirection of other tendons to the thumb, index finger, or wrist, was done in eight cases. Two of these thumbs had carpometacarpal fusion for hypermobility, in addition to the tendon transplantation. The results were excellent in six of this series.

2. A free graft, the peronaeus longus tendon with the flexor carpi ulnaris being used as the motor, was applied in two cases. The results were excellent in both.

3. Rotation osteotomy of the proximal phalanx of the thumb toward the palm without tendon transplantation was done twice. A good "pincher" movement was obtained in each case, but the appearance of the thumb was poor.

4. Synostosis of the thumb and index-finger metacarpal was performed in four cases. The result was not good in any one, but the procedure cannot be condemned on this basis.

5. The Steindler tendon transplantation was done on two thumbs. The end result in neither of these was satisfactory.

CONCLUSIONS

1. In the early treatment of paralytic deformities of the hand, the prevention of soft-tissue contractures and joint changes is important.

2. Transplantation of the flexor digitorum sublimis of the ring finger to the proximal phalanx of the thumb has given the most satisfactory results in this Clinic, and has fulfilled all the requirements of opposition and increased strength.

3. Before operation is done, certain prerequisites must be fulfilled. The type of surgical procedure used depends upon the existing anatomy of the hand. The result will depend upon the proper choice of procedures.

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SOME OBSERVATIONS ON THE CIRCULATION IN FOETAL AND INFANT SPINES *

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The human spine has been studied externally for many centuries; however, compared to other tissues of the human body, very little is known about its intrinsic anatomy, physiology, and pathology.

A search of the literature has failed to reveal how the blood from the left side of the heart nourishes the tissues of the spine and returns to the right side of the heart. The

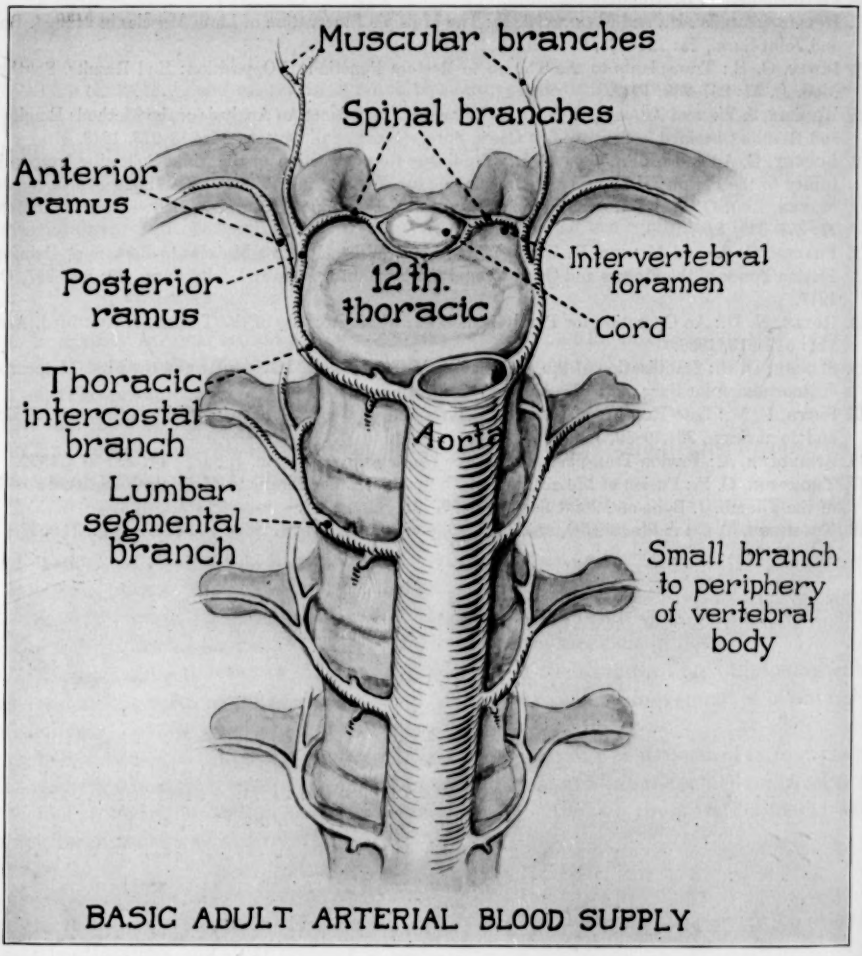

FIG. 1

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 25, 1949.

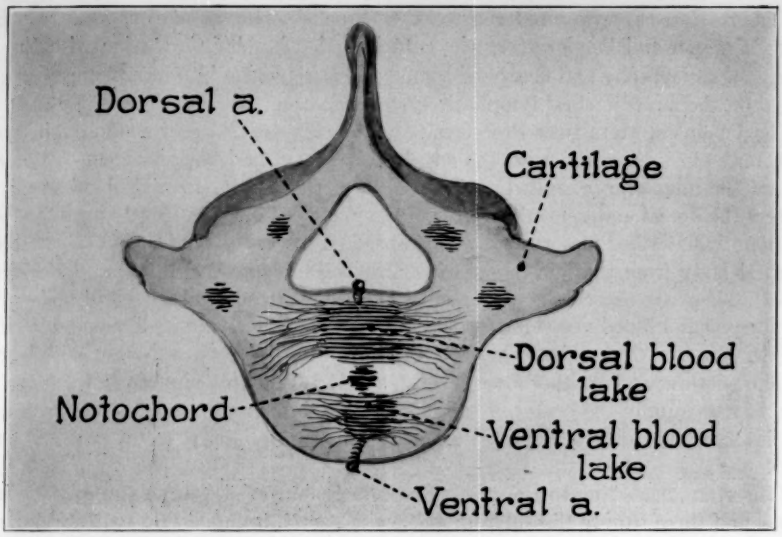

FIG. 2

Schematic drawing of transverse section of the foetal arterial blood supply, based on description of Böhmig.

usual anatomical descriptions and pictures are concerned with the principal arteries and their branches to the external surfaces of the vertebral segments (Fig. 1). The textbooks of anatomy are not clear regarding the spinal branch after it leaves the posterior ramus and passes through the intervertebral foramen.

Several workers, interested in developing our knowledge of the circulation to the spine, have centered their attention on the smaller branches of the arterial supply and the patterns of venous drainage of the vertebral segments and the spinal canal. Among them

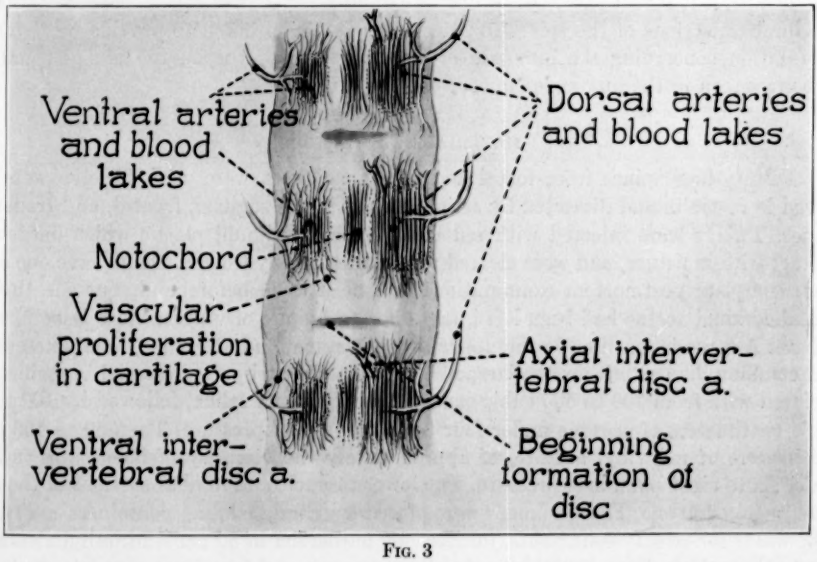

FIG. 3

Schematic drawing of sagittal section of foetal arterial blood supply, based on description of Böhmig.

are Robert Hanson, who cited the work of Froelich, Hahn, Köhler, Mau, Koch, and Lexer; Wagoner and Pendergrass, who contributed valuable information with the aid of roentgen arteriography and described a sinusoidal circulation in the centrum; Varno, who worked on the paravertebral lymphatic system; Batson, who described "The Role of the Vertebral Veins in Metastatic Processes" and demonstrated the "vertebral-vein system" which ranks in importance with the caval, pulmonary, and portal venous systems; and Richard Böhmig, who presented an interesting picture of the arterial blood supply after it enters the dorsal and ventral surfaces of the vertebral body in foetal and infant spines.

Böhmig described major vessels which proceed toward the center of the cartilaginous vertebral body from the mid-points of the ventral and the dorsal surfaces, respectively, (Fig. 2). These are named the dorsomedial and the ventromedial vertebral-body arteries. The dorsomedial blood vessel sends a large branch superiorly, as well as one inferiorly to the intervertebral-disc regions (Fig. 3). The ventromedial vertebral-body vessel presents a similar picture; and another artery leads superiorly as well as inferiorly from the dorsal blood lake to supply the center of the intervertebral-disc area. This has been named the axial intervertebral-disc artery by Böhmig, and it runs adjacent to the path of the notochord.

Therefore, according to Böhmig, three principal arterial channels supply the inferior surface and three supply the superior surface of each developing intervertebral disc; and the dorsal, axial, and ventral intervertebral-disc arteries send out lateral, dorsal, and ventral branches as they advance through the cartilaginous zone. In the region of the developing hyaline-cartilage plate, the ramifications of the three intervertebral-disc arteries anastomose and send myriad channels into the developing disc tissue. These channels in the developing annulus fibrosus are so small that they resemble paint-brush lines, even though magnified nineteen times. According to Böhmig, they are tiny vessels with capillary walls containing red blood corpuscles, and may possibly be arranged in patterns of an artery with two veins. It is presumed that they account for the pattern of the fibers in the fully developed annulus, because connective-tissue fibers appear to emanate from them as well as from those arterial branches which Böhmig also states perforate the hyaline-cartilage plate.

The present investigation deals only with the arterial anatomy of the lower thoracic and lumbar sections of the spine. It reflects the first step taken to provide more factual information concerning the influence of circulatory factors upon the diseases and disturbances seen in the human spine today.

MATERIAL AND METHODS

Twenty-four spines from foetal and infant cadavera were used. Twelve were preserved in formalin and dissected by serial sections in the sagittal, frontal, and transverse planes. Twelve were injected with red vinyl acetate, a liquid plastic which hardens on contact with moisture, and were cleared with potassium hydroxide. On all save one specimen, complete postmortem examinations had been done beforehand, but the thoracic and abdominal aortae had been left intact. The technique of vinyl acetate injection is as follows: A cannula was tied in the upper thoracic aorta, and the celiac, renal, mesenteric, and common iliac arteries were clamped off. The aorta and paired arterial branches were perfused with from 300 to 500 cubic centimeters of normal saline, followed by 100 to 200 cubic centimeters of acetone under four to six pounds of pressure. Then 50 to 100 cubic centimeters of red vinyl acetate, of approximately the viscosity of blood, was injected under six to eight pounds of pressure. The lower thoracic and lumbar sections of the spine were removed *in toto*. The specimens were placed in cylindrical glass containers and treated with water for twenty-four hours, followed by hardening in 80 per cent. ethyl alcohol for one to three days. Potassium hydroxide in a strength of 2.5 to 5 per cent. was then used to clear the spinal tissue; this required from seven to fourteen days. Finally the specimens

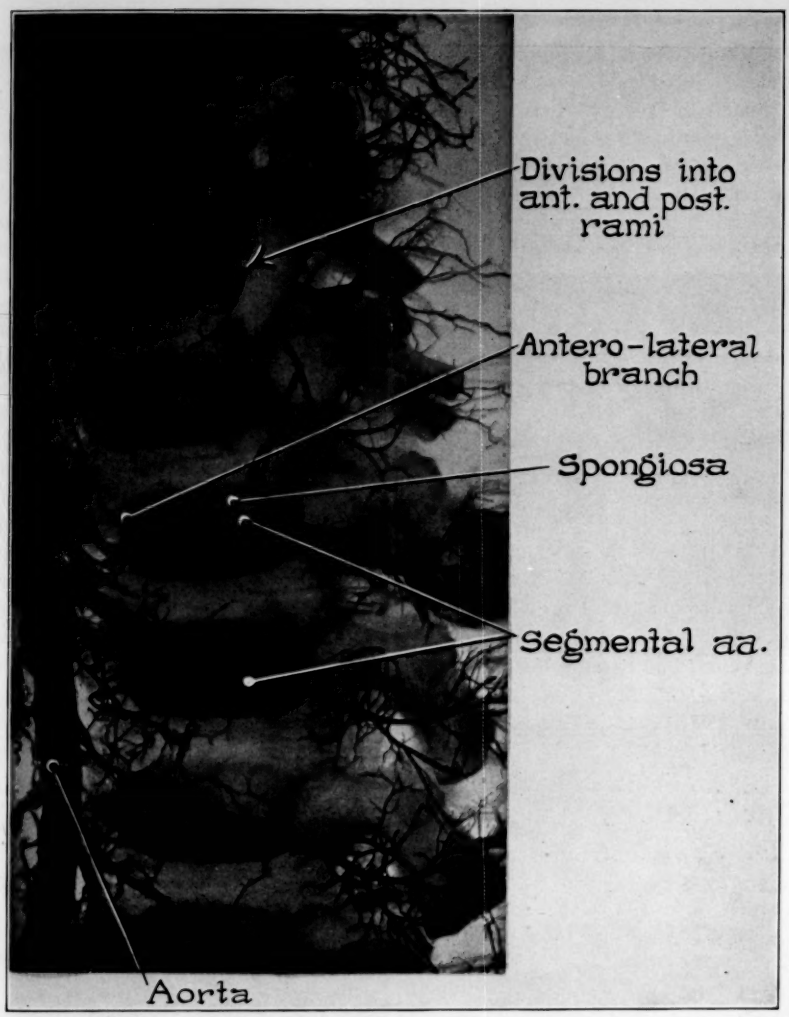

FIG. 4

Lateral view of a foetal thoracolumbar spine. Arterial supply has been injected with vinyl acetate and the tissues have been cleared with potassium hydroxide. (This is more illustrative in color and the third dimension.)

were treated with from 20 to 60 to 80 per cent. glycerin and sealed in 100 per cent. glycerin with a few crystals of thymol. This clearing technique is a modification of that described by Miller and used in the Department of Embryology, Carnegie Institution of Washington, to demonstrate ossification centers in the cartilaginous skeleton.

When light was directed through the cleared specimens, the arterial system was seen to be filled with red vinyl acetate which resisted the potassium hydroxide. In many instances, the arterial tree was demonstrated to the point of extremely fine branches.

Two additional spines were injected with vinyl acetate in the manner already described, and serial sections were made in the sagittal, frontal, and transverse planes.

Staining of microscopic cross sections was done to determine the character of vessels seen in the spongiosa, cartilaginous zone, and disc areas of the vertebral bodies.

FIG. 5-A

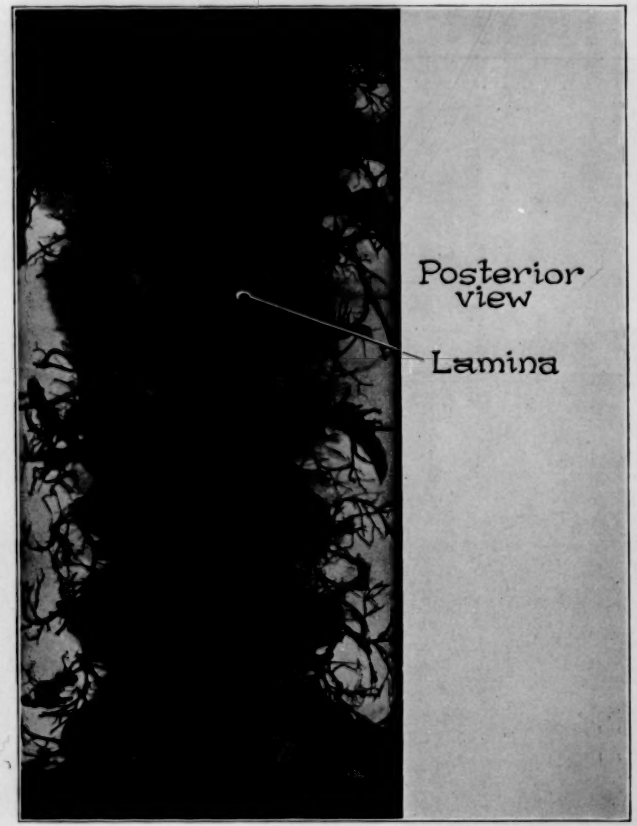

FIG. 5-B

Fig. 5-A: Lumbar vertebral segment has been removed, showing dorsomedial vertebral-body artery from the rich arterial anastomoses in the spinal canal.
Fig. 5-B: Rich arterial anastomoses around pedicles, facets, and laminae, and also in spinal canal.

OBSERVATIONS

Examination of the sections of the spines treated with formalin merely created questions. Arteries and veins were noted, encircling the vertebral bodies at their middle thirds. Vessels entered or left a funnel-shaped opening in the central dorsal surface of each vertebral body. The calcified center of the vertebral body increased from approximately 1 centimeter to a large mass of bony spongiosa between the seventh and tenth months of foetal life. Large numbers of vascular channels were seen in the spongiosa and in the cartilaginous zones, and the walls of these vessels were more venous than arterial.

In those specimens injected with vinyl acetate, tiny branches were observed, leading from the paired segmental arteries to the periphery of the vertebral body (Fig. 4). Most of these stopped in the ligamentous tissue; only a few penetrated the cartilaginous centrum more than a millimeter. Small branches pierced the anterolateral aspects of the vertebral body and penetrated deeply into the horizontal cleft of the ossifying spongiosa (Fig. 5-A). The pedicles, transverse processes, and facets received a rich arterial supply from the posterior rami. The spinal branch which entered the spinal canal through the intervertebral foramen was always prominent, and the posterior ramus entered into rich anastomoses over the laminae and around the spinous processes (Figs. 5-A and 5-B).

The spinal branch presented many patterns of division after it passed through the intervertebral foramen. Frequently one division proceeded cranially, the other caudally, to supply adjacent vertebrae. There was always an extensive anastomosis in the spinal canal with divisions of the opposite spinal branch and with those above and below. Small arteries from these anastomoses formed plexus around the meninges and contributed to the longitudinal arteries of the spinal cord (Fig. 5-A). Usually one prominent artery from the anastomosis in the floor of the spinal canal entered the rather large and funnel-shaped

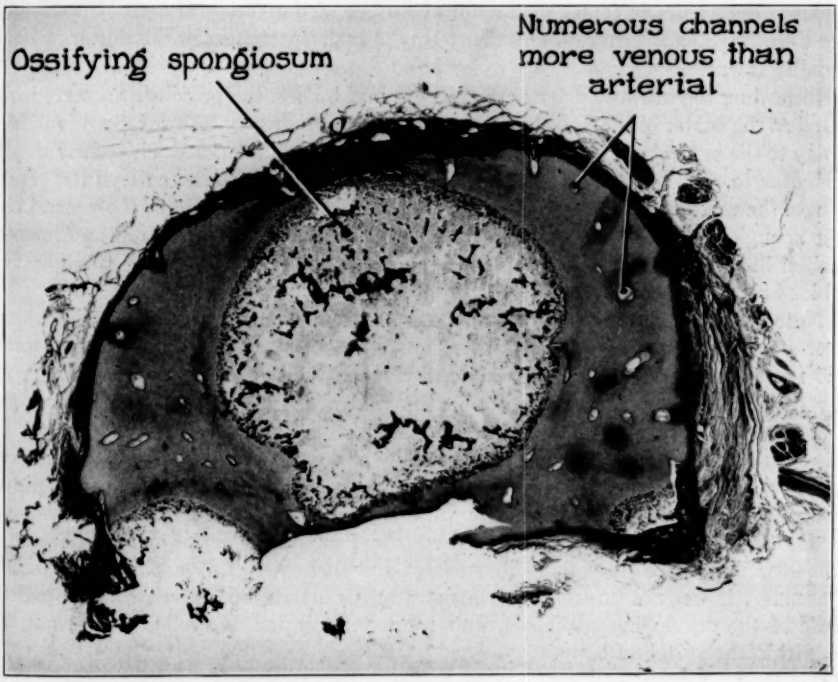

FIG. 6

Transverse section (× 7) of cartilaginous zone adjacent to osseous spongiosa. The channels appear to be more venous than arterial, and did not receive any of the vinyl acetate injected into the aorta. (*Ossifying spongiosum* on drawing = *substantia spongiosa of bone.*)

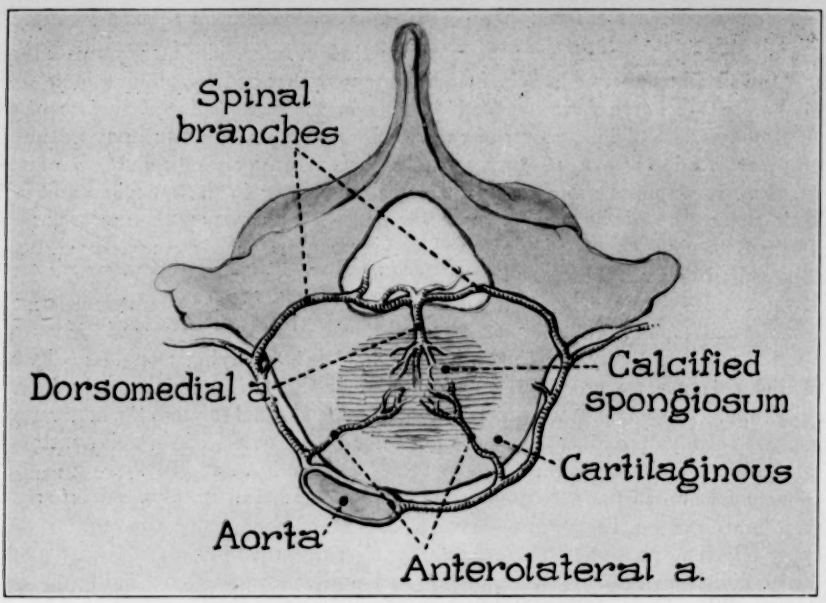

FIG. 7

Author's interpretation of a transverse section through the mid-body of a six-month foetus. (*Calcified spongiosum* on drawing = *substantia spongiosa of bone.*)

foramen, directly in the center of the dorsal surface of the vertebral body. Occasionally there were two smaller arteries, and many tiny branches were lost in the posterior longitudinal ligament.

Regarding the intrinsic arteries of the vertebral bodies, the prominent artery, which entered at the center of the dorsal surface (Fig. 5-A), ran directly forward three-fourths of the way to the ventral surface. It gave many branches in all directions as it passed into the calcified or osseous spongiosa of the centrum. Likewise, small arteries entered the ventral aspect of the vertebral body from an anterolateral direction. They entered the ventral zone of the spongiosa through a horizontal slit. Branches of the mid-dorsal and anterolateral vertebral-body arteries ended in the developing spongiosa, and appeared to empty into the blood sinuses there.

Numerous channels in the cartilaginous zones were seen again, but none of these contained a trace of vinyl acetate (Fig. 6). The stained sections demonstrated thin-walled blood vessels. Sometimes they were more obvious in the dorsal half of the centrum; at other times they were more numerous in the ventral half. There were communicating channels to the periphery of the vertebral body in the ventral half. Such channels are named here the cartilaginous-zone vessels; they were most prominent at the junction between the developing osseous spongiosa and the cartilaginous zone. The cartilaginous-zone vessels appeared to communicate with the advancing spongiosa, the developing disc tissue, and the periphery. Very small vessels of some type perforated the developing hyaline-cartilage plate throughout its surface; and there were tiny capillary channels in the annulus. It was not possible to demonstrate true arteries in the centrum beyond the middle of the developing spongiosa, and more information is needed concerning the area within the vertebral body.

DISCUSSION

This investigation carries our knowledge of the arterial side of the circulation a little further, but it does not show the final disposition of the arterial blood within the vertebral

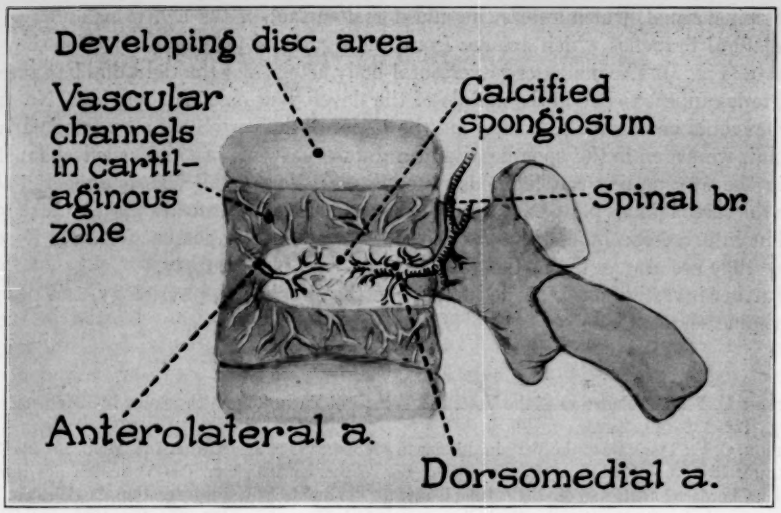

FIG. 8

Author's interpretation of a sagittal section through the mid-body of a six-month foetus. (*Calcified spongiosum* on drawing = *substantia spongiosa of bone.*)

segments. Böhmig claimed that there are dorsal, axial, and ventral intervertebral-disc arteries, but we could not find them. The vinyl acetate injections may have been too crude for the intrinsic arteries of the centrum. On the other hand, we recognized an extensive vascular system in the developing spongiosa and cartilaginous proliferation tissue, which is probably the sinusoidal system described by Wagoner and Pendergrass or the vertebral-vein system described by Batson.

The pedicles, facets, laminae, and spinal canal are richly supplied with arterial anastomoses, while the centrum has a relatively poor supply. The disc tissue is the farthest from arterial blood and appears to depend upon the ebb and flow of secondary channels for nourishment. Such fine channels of supply, no matter how numerous in foetal or infant spines, are precarious, and they become progressively so with age. If disease, injury, vasospasm, poor diet, faulty metabolism, or other factors should exert their influence upon this poor arterial circulation of the vertebral body and adjacent discs, then we should expect active foci of degeneration in these tissues.

There is much more to know about the peculiar circulation of the spine. It is expected that further investigations, especially of the venous circulation, will help make clear the final disposition of arterial blood in the centrum.

It would be very interesting to determine the role of oxygen tension in the development of the principal components of the spine; for example, disc tissue is to centrum as low oxygen tension is to higher oxygen tension.

SUMMARY

A step has been taken toward the clarification of the arterial circulation in the spine, particularly the intrinsic circulation of the vertebral body. Twenty-four foetal and infant spines were used. Twelve were preserved in formalin and dissected. Twelve were injected with vinyl acetate and cleared with potassium hydroxide. Selected sections of the vertebral bodies were made and stained.

The pedicles, transverse processes, articular facets, and laminae have a good arterial blood supply through the anastomosing branches of the posterior rami from the paired segmental arteries of the thoracic and abdominal aortae. The only arteries to the vertebral body worthy of the name are: a fairly prominent branch of the anastomosis in the floor

of the spinal canal, which enters the mid-dorsal surface of the centrum; and two small anterolateral branches which emerge from the segmental arteries soon after they leave the aorta (Fig. 7). The main dorsal vertebral-body artery and the right and left anterolateral arteries appear to end in the middle of the developing osseous spongiosa. No arterial branches could be demonstrated beyond the center of the vertebral body. Irregular vascular canals were seen in the spongiosa, and a diffuse network of thin-walled channels was seen in the surrounding cartilaginous zone (Fig. 8). Very small vessels appeared to perforate the cartilaginous plate, and tiny capillary channels to permeate the annulus fibrosus.

The intervertebral-disc tissues still appear to offer an important focus for degeneration, as they are always the farthest from the arterial blood supply.

Further investigation is needed to explain the circulation, physiology, and pathology of the spine segments.

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DISCUSSION

Dr. J. Albert Key, St. Louis, Missouri: This is fundamental work. It should be continued to the point where the cartilage is replaced by bone, and the bone reaches the stage found in adult life. The circulation which is described here changes; in adolescence, the blood vessels which pierce the annulus and the cartilage plates degenerate, and the blood supply to the nucleus is interrupted permanently.

The disc shows early evidence of degeneration. It is possible that part of this is due to an inherent tendency of cartilage to degenerate; another factor is that the notochord is a foetal tissue which is doomed to degenerate. I agree that the disc is one of the tissues farthest from the circulation. I believe that the nutrition of the interior of the disc (the nucleus pulposus) seeps through the cartilaginous plate, which is closely associated with cancellous bone. This cancellous bone of the body of the vertebra has a rich circulation and is not separated from the cartilage plate by a layer of dense bone.

I also believe that the variations in pressure to which the disc is subjected have something to do with the flow of fluid to and from the disc. When a man stands or sits erect, the pressure in the disc is increased by the pressure of the superincumbent body weight. When he moves from the vertical plane, the pressure is increased by leverage, and may be tremendous. The disc arm of the lever is relatively short. When he lies down, sleeps, and is relaxed, the pressure from above is removed and his muscle tone is lessened. Thus the turgor or internal pressure of the disc is lessened at night. At that time, fluid can seep into the nucleus through the cartilage plate and possibly through the annular ligament. During the day, when a person is active, this fluid is forced out. We know that these tissues are able to get along with very little material for consumption. However, due to their lack of blood, they must be starved from time to time, and this may be one cause of their early degeneration.

OBSERVATIONS ON DISCOID MENISCI

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From the Clinic of the New York Orthopaedic Hospital, New York City

Twenty-one discoid menisci have been observed in eighteen patients operated upon at the New York Orthopaedic Hospital between 1934 and 1949. A presentation and discussion of the significant findings in these cases form the basis for this report. No case of discoid meniscus was included in this series which had not been adequately described at the time of operation or in the pathology laboratory. Thus, several cases of a meniscus "wider than normal" or "almost discoid in type" could not be considered in this study.

In a fifteen-year period from January 1934 to January 1949, inclusive, 580 medial meniscectomies were performed. A discoid medial meniscus was observed but once, an incidence of 0.17 per cent. In the same period, 129 lateral menisci were excised and a discoid form was noted in twenty cases, an incidence of 15.5 per cent.

In the majority of cases of discoid meniscus reported in the literature, the patients were in the second decade of life at the time of operation, varying in age from two years to over fifty.

The youngest patient in the author's series was eight years of age and the oldest was forty-one. The average age was 17.3 years. No predilection was shown for either sex. There were nine female and nine male patients.

The right knee was the site of a discoid meniscus in eleven cases and the left in ten. Bilateral involvement was proved by operation in two cases, an incidence of 11 per cent. Symptoms in the unaffected knee may not appear for a number of years, or possibly not at all. It is not surprising, therefore, that only a small number of cases with excision of discoid menisci from both knees have been reported. In a series of twenty-nine discoid menisci reported by Smillie in 1948, only one bilateral case is mentioned. Six other cases have been reported to date, by Ellis, Duncan, Lloyd, Herzmark, Fairbank, and Kulowski.

DISCOID MEDIAL MENISCUS

As late as 1941, no case of discoid medial meniscus had been recorded in the literature, and it was generally accepted that the persistence of the discoid embryonic form was peculiar only to the lateral meniscus. Dwyer and Taylor reported the "first" case of its kind in 1945. Smillie, in 1946, added a second case. These authors make no mention of the two cases of partly discoid meniscus, reported by Cave and Staples in 1941.

One case in the present series was unique in that discoid lateral and medial menisci were encountered in the same knee. A review of the literature has convinced the author that this is the first case of its kind to be reported.

P. C., a girl, aged ten, was first seen in this Clinic in 1933 because of pain, swelling, and inability to fully extend the right knee. These symptoms had been present intermittently for six months; no history of trauma could be elicited. The past history was relevant in that an abscess of the right thigh, just above the knee, had developed at the age of eight months. Roentgenograms revealed irregularity of the joint margins with genu valgum. The patient was not seen again until four and one-half years later. During that time she had had pain and stiffness in the right knee, particularly in bad weather. When she ran, the right leg had a tendency to "turn out" and the knee felt unstable.

Physical examination showed moderate swelling in the right knee. The range of motion was complete, but pain occurred along the anterior aspect of the joint at the extremes of flexion and extension. There was 30 degrees of external rotation of the tibia at the knee joint. When the knee was flexed, the tibia went into valgus position and the patella became subluxated laterally.

In June 1938, the medial compartment of the right knee was explored and an abnormally wide, pear-shaped medial meniscus was encountered. This measured 6 centimeters in length, 2.7 centimeters in greatest width, and 0.8 centimeter in thickness. At the superior surface, one slightly roughened ridge crossed the posterior third transversely. The inferior surface was gently convex and was roughened. At the inner margin an opening, 2 centimeters long, led into a cavity in the substance of the meniscus, which divided the specimen

into upper and lower leaves over an area measuring 2.5 by 2 centimeters. The articular cartilage was irregular and showed degenerative changes.

The patient was readmitted to the Hospital four years later (in June 1942), complaining that for the past two months she had been noting marked crackling in the right knee, which got "caught" two or three times daily while she was working, so that she lost step and had a tendency to fall. After massaging the knee and "limbering it up", the joint unlocked from the semiflexed position and motion was resumed.

Physical examination disclosed a full range of painless motion in the right knee, accompanied by marked crepitation. There was no effusion. A firm, non-tender mass was noted on the lateral aspect of the joint space.

The lateral compartment of the right knee was explored in June 1942 and a thick, disc-shaped lateral meniscus was found, extending over the entire articular surface of the lateral portion of the tibial plateau. The meniscus was loosely attached, and slipped about very easily during flexion and extension of the knee. Microscopic examination revealed mucoid degeneration centrally, in the substance of the fibrocartilage.

ANATOMY OF THE DISCOID MENISCUS

The majority of the specimens were complete discs, oval or roughly circular in shape, covering the entire articular surface of the tibial plateau. The inner margin was either slightly flattened and attached throughout its length along the intercondylar space and cruciate ligaments, or it presented a small free indentation at its middle. Less frequently, the body and the anterior horn were abnormally wide, while the posterior horn was within normal limits. Middleton described this form as "comma-shaped"; he believed it quite possible that a similar condition, affecting the body and the posterior horn only, might occur. One such specimen was seen in this series.

Another discoid meniscus presented a broad anterior half and a rudimentary posterior horn. In still another case the superior surface was oval in shape, and the inferior surface was formed by a normal-appearing meniscus, the two joined together at the periphery.

TYPE OF LESION ENCOUNTERED

A horizontal tear or splitting of the fibrocartilage through its transverse axis was noted in seven of the specimens. This tear included both lateral discoid menisci in one patient and a medial discoid meniscus in another. A history of trauma was elicited in only three of these seven cases.

The mechanism of horizontal tear has been well explained by Smillie [17]. He attributed this splitting or cleavage to the continuous movement of the relatively free superior surface on the relatively fixed inferior surface of the abnormally thick meniscus. In one discoid meniscus of this series, the horizontal split was strictly central; in two specimens it extended from the periphery inward; and in four specimens, from the inner margin toward the periphery. This type of lesion accounted for locking in three cases.

A longitudinal tear was encountered in one case, extending through two thirds the length of the inferior surface, opening into a cystic cavity in the substance of the meniscus. In another case, there was a partial tear in the anterior portion of the cartilage. The torn fragment, which was doubled up and wedged between the tibial and femoral condyles, accounted for the locking noted preoperatively.

A ragged, frayed-edged hole, 1 centimeter in diameter, was the chief pathological feature in one case; "fenestration" was noted in the center of another specimen.

Detachment of the meniscus was observed in three cases. As pointed out by Middleton, whenever the knee is brought close to full extension, the femoral condyle rides over the anterior edge of the loose discoid meniscus, which is then forced backward toward the posterior compartment of the joint. It can be readily seen that, when this is repeated often, the anterior peripheral attachments of the meniscus suffer from the abnormal forces of tension and vertical compression. Eventually, the ligaments become stretched and attenuated, and they finally yield, causing complete detachment. In one case, the anterior half of the discoid meniscus was completely detached and was displaced toward the intercondylar notch. The only trauma sustained by the patient was a relatively mild hyperextension injury. In two other cases, the anteromedial peripheral attachments were torn,

while the anterior horn remained firmly anchored. These patients gave no history of injury.

The reverse may also be true,—that is, one may note stretching, attenuation, and detachment of the posterior peripheral ligaments. There were no such cases in this series.

In the remaining seven discoid menisci, there were no gross tears and no detachment; three of these menisci were noted to be abnormally loose, allowing considerable backward and forward motion in extension and flexion of the knee.

CYSTIC DEGENERATION

In five of the twenty-one specimens (23.8 per cent.), microscopic examination of cross sections revealed a centrally located cavity, bordered by walls showing mucoid degeneration and areas of microcystic degeneration. In another specimen, it was noted on gross examination that the "central part felt cystic". However, no microscopic studies were done on this case. Gross cysts were noted peripherally in four other discoid menisci (19 per cent.), and a diagnosis of "cyst of the lateral meniscus" was made preoperatively in all four of these cases.

Thus, 42.8 per cent. of the discoid menisci in this series revealed either central mucoid degeneration in the substance of the fibrocartilage, or gross peripheral cysts.

CLINICAL FEATURES

The classical, but by no means constant, sign is the loud "clunk" heard and felt in the last 15 to 20 degrees of flexion and extension of the knee, accompanied by a jolt which interrupts the smooth movement of the joint. This dramatic sign was elicited in only three of the twenty-one cases. It either causes no pain or, at most, may produce an uncomfortable feeling. When present, it is pathognomonic of a discoid meniscus. The vast majority of discoid menisci that are operated upon, however, do not produce a "snapping" knee. The symptoms and objective findings on physical examination are not at great variance with those resulting from injury or cyst. The usual picture in this series is that of a patient in the second decade of life who complains of mild, intermittent ache on the lateral aspect of the knee, appearing either after injury (in 30 per cent.) or insidiously, without apparent cause (in 70 per cent.). Weakness, instability, or "giving way" may be a dominant complaint. There may be a history of locking even in the absence of significant trauma, or the patient may note inability to fully extend the knee, causing him to walk with a limp. Physical examination may show a firm, localized swelling on the lateral aspect of the joint line, which moves during flexion and extension of the knee. This may or may not be tender to pressure, and may often be interpreted as a cyst of a lateral meniscus. Mild tenderness over the meniscus may be noted in the absence of any palpable swelling. Except in cases with recent significant trauma, no effusion is noted. Motion is painless, but attempted hyperextension may elicit mild pain on the lateral aspect of the joint. A mild "click" may be noted on flexion and extension of the knee. Atrophy of the thigh is significantly absent except in cases complicated by injury.

ROENTGENOGRAPHIC FINDINGS

Roentgenograms may be of some aid, when comparable views of both knees are taken on the same plate. In four cases of this series, definite widening of the lateral joint space was noted on the affected side, as compared with the unaffected knee. Since there is a wide variation in the thickness of the discoid menisci (from 0.5 to 1.3 centimeters in this series), it is to be expected that only the thickest menisci will show widening of the joint space.

In two cases, hypoplasia of the lateral femoral condyle was also evident and could be measured by superimposing tracings of the roentgenograms. In another patient (whose roentgenograms unfortunately could not be located) the tibial tubercle was transplanted because of recurrent subluxation of the patella.

RESULTS OF TREATMENT

Nine patients were followed for periods ranging from five to twelve years after operation. The results were excellent in eight of these cases. In one case where the end result was rated as "good", degenerative arthritic changes were noted prior to operation in the knee from which discoid medial and lateral menisci were later excised. Although much improved after surgery, the patient still complained of a mild ache and crepitation on exertion and in bad weather. In another patient, from whom discoid lateral menisci were excised bilaterally at the ages of fifteen and sixteen, moderately advanced osteo-arthritis developed in both knees six years after operation. He was asymptomatic when last seen. Roentgenograms of the other patients revealed no pathological changes.

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WEDGE OSTEOTOMY FOR FRESH INTRACAPSULAR FRACTURES OF THE NECK OF THE FEMUR

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A critical analysis of the many end-result studies on intracapsular fractures of the neck of the femur shows that the percentage of failures is still too great and that further investigation of present-day methods of treating these lesions is necessary.

Boyd and George, in 1947, reported the following findings in a series of cases from the Campbell Clinic: 43.6 per cent. of good results, 28.1 per cent. of poor results, 19 per cent. of fair results, and a mortality of 9.3 per cent. Of the poor results, 13.5 per cent. were due to non-union. More recently, Neer and McLaughlin made a detailed, comprehensive report of 104 intracapsular fractures with displacement, of which seventy-three were treated by open reduction and thirty-one by closed reduction. These observers recorded the following end results: In the series treated by the open method, non-union was encountered in 21.9 per cent. and aseptic necrosis in 42.0 per cent. of the cases; in the series treated by closed reduction and lateral nailing, non-union was disclosed in 16.1 per cent. and aseptic necrosis in 54.0 per cent. Such high levels of failures are alarming and justify a revision of present methods, even if some of the accepted concepts referable to the treatment of intracapsular fractures are challenged.

This article is being presented as a preliminary report on forty consecutive cases of transcervical fracture of the neck of the femur which conform to Pauwels' Types II and III. In all instances a wedge osteotomy was performed through the distal fragment of the neck, so that the head could be placed in a position of valgus. A similar procedure was described by Voss in 1937. Although the present series of cases is small, the results to date have been encouraging, and they suggest that a revision of the following concepts be considered:

Open Method

It has long been maintained that open reduction in elderly individuals with fracture about the hip joint tends to raise the mortality rate and increase the number and severity of postoperative complications. Statistics show that this is a misconception. Open operations, done by men competent in hip surgery, do not increase the mortality rate or the postoperative sequelae. Neer and McLaughlin recorded an operative mortality of 1.3 per cent. in cases treated by the open method, and 3.2 per cent. in those treated by the closed method.

In the author's series there were no operative deaths, nor any related to the operative procedure. There were no wound infections or instances of thrombophlebitis.

Non-Union

There is a general belief that open reduction adds further trauma to the already embarrassed blood supply of the femoral head and neck in intracapsular lesions, thereby leading to a greater incidence of non-union. Statistical appraisal fails to substantiate this conception. The percentages of non-union reported by Neer and McLaughlin for open and closed reduction (21.9 per cent. and 16.1 per cent., respectively) differ too slightly to be of any significance, since only thirty-one cases were treated by the closed method. Spotoft recorded unusually good results in a series of fifty cases which had been studied for at least three and one-half years. His incidence of non-union was 6 per cent.; that of necrosis of the head was 16 per cent. He attributed his good results to early treatment

and gentle reduction, in order to avoid vascular injuries; good reduction; proper placement of the nail; and a long period of immobilization.

In the present study, non-union occurred in 10 per cent. of the cases.

Non-union is due primarily to hyperaemia at the fracture site, which promotes absorption of the distal cervical fragments. Such absorption is also caused by sheering forces at the fracture site, which result from inadequate reduction, poor nailing, and the plane of the fracture, even when there has been good alignment and the nail has been properly placed. In all instances of non-union in the author's cases, absorption of the distal fragment of the femoral neck was a constant feature. Roentgenographic study of this area reveals, in the early phases, generalized decalcification followed by fragmentation and absorption of the bone elements. These observations are consistent with increased vascularity at the fracture site, and not embarrassment or total occlusion of the blood supply.

Avascularity or diminished vascularity of the capital fragment does not in all instances result in non-union. It is generally accepted that non-viable heads will unite under proper mechanical conditions; however, it must be admitted, as pointed out by Phemister, that union is more prone to take place in the presence of a live head. In this group of cases, one head exhibited roentgenographic evidence of aseptic necrosis before bony union occurred. Elimination of all sheering strains at the site of fracture is the most significant factor in attaining union. This belief receives support from the observation that the prognosis in impacted valgus fractures of the neck, conforming to Pauwels' Type I, is much more favorable than in Types II and III, in which the angle of inclination of the fracture line is 50 degrees or over. This observation indicates that the sheering forces in Type I are more readily neutralized by adequate internal fixation than in the other two types. It is reasonable to assume, therefore, that the ideal method of management is one which converts all sheering forces at the fracture line into impacting forces which are known to stimulate osteogenesis. In theory, a wedge osteotomy through the distal cervical fragment fulfills all these requirements; in practice, the end results in forty cases justify the acceptance of this procedure.

Aseptic Necrosis

This sequela is now the source of greater concern than non-union. It may become evident as early as the third month, but usually roentgenographic manifestations are noted between the ninth and twelfth months and occasionally between the twenty-fourth and thirty-sixth months. The incidence reported from different clinics varies from 33 per cent.[1] to 54 per cent.[5]. Open reduction does not increase the incidence.

In this series, in twenty-two patients all seen more than eighteen months after operation, there were four cases of aseptic necrosis (18.1 per cent.). However, this series is too small to draw any final conclusions relative to the incidence of aseptic necrosis; the incidence may be greater after a three-year follow-up period.

TECHNIQUE OF OPERATION

The hip joint is exposed through a Callahan incision[3] (Fig. 1), which begins just distal to the anterosuperior spine and extends downward to a point approximately one-third the distance from the spine to the knee; it then curves posteriorly to a point slightly beyond the posterior margin of the femur. The plane between the sartorius and the tensor fasciae femoris is then developed, and the fascia lata is divided transversely in the lower portion of the incision. The reflected head of the rectus femoris is divided and retracted medially, while the tensor fasciae femoris and the glutaeus medius are displaced posteriorly, thus exposing the joint capsule. By first identifying and ligating the lateral circumflex vessels, a bloodless field is attained. Fracture fragments are exposed by incising the capsule parallel to the neck, from the intertrochanteric line to the rim of the acetabulum. If more exposure is desired, the capsule is divided transversely at its insertion.

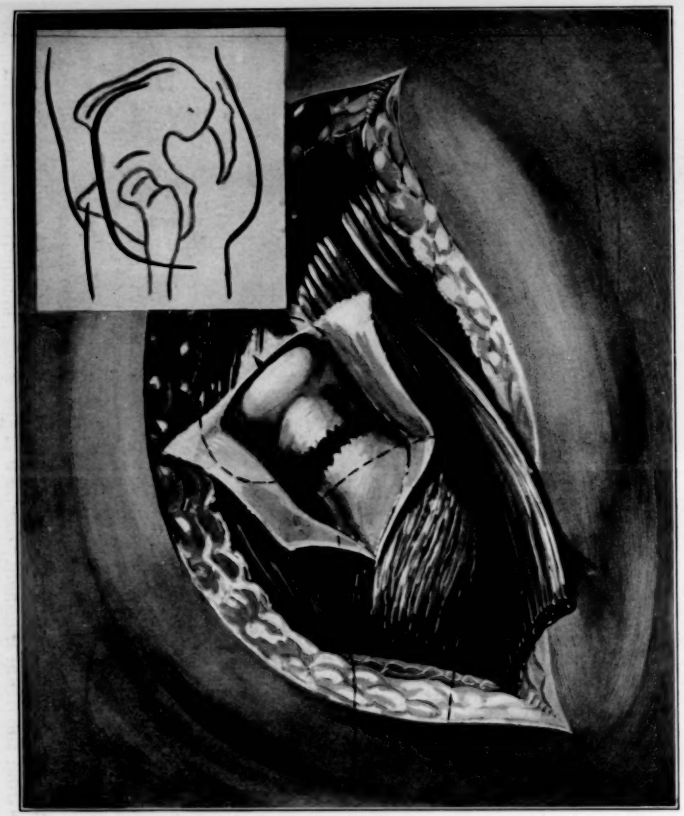

FIG. 1

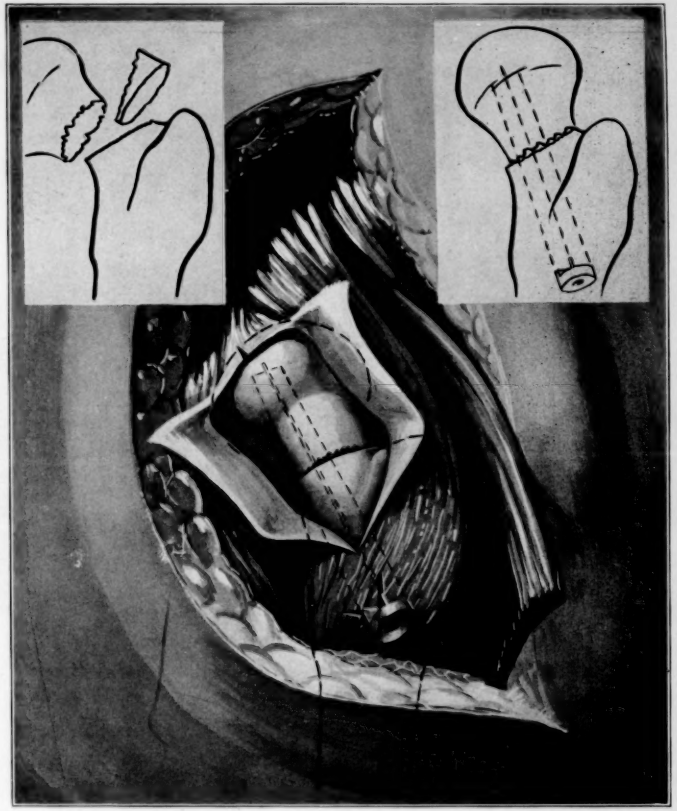

FIG. 2

Fig. 1: Exposure of hip joint by Callahan's incision.
Fig. 2: Illustrates removal of wedge from the distal fragment of the femoral neck, replacement of the head fragment in a valgus position, and fixation of fragments with a Smith-Petersen nail.

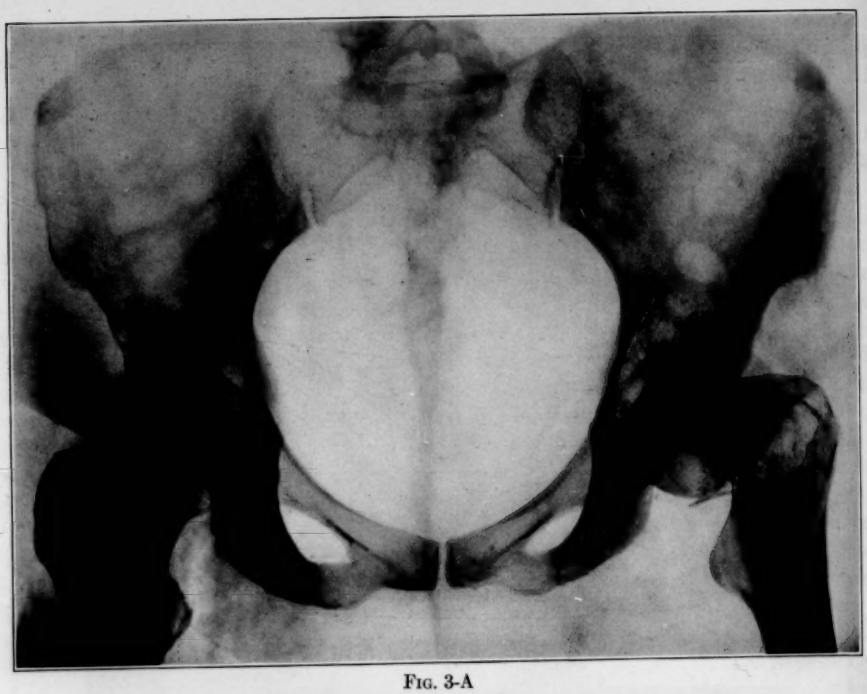

FIG. 3-A

Adduction fracture of the femoral neck.

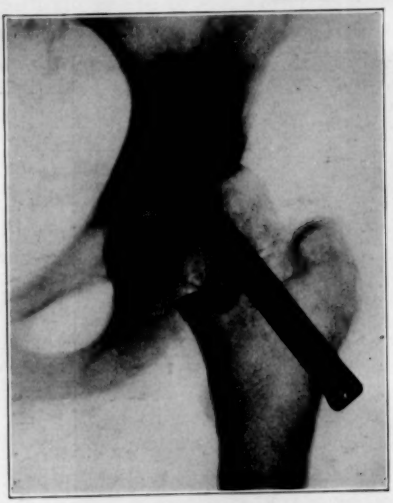

FIG. 3-B

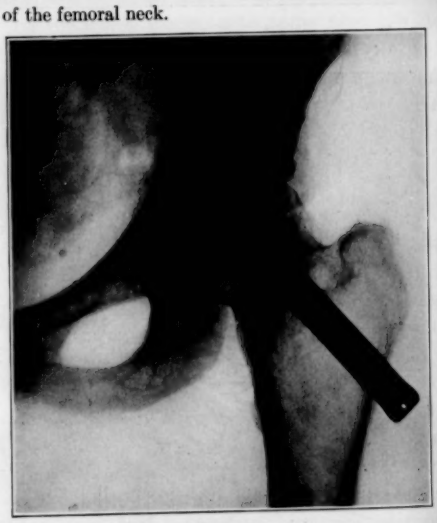

FIG. 3-C

Fig. 3-B: Roentgenogram after removal of wedge of bone from the proximal fragment of neck and replacement of the capital fragment in a valgus position.

Fig. 3-C: Roentgenogram taken two years later. Note new-bone formation along the inferior aspect of the neck, bridging the proximal and distal fragments. No vascular complications of the capital fragment are discernible.

By traction and external rotation of the extremity, the fragments are disengaged and the fractured surface of the distal fragment comes into view. A wedge of bone is next removed from the distal fragment; the base of the wedge is superior while its apex is in-

ferior. The width of the base depends upon the obliquity of the fracture line; the more the fracture line approaches the vertical plane, the greater is the width of the base. Sufficient bone should be removed so that an adequate plateau is made for the capital fragment. The size of the wedge removed should be as small as possible to achieve the desired position. If too large a segment of bone is removed from the distal fragment of the neck, great difficulty may be encountered in approximating the two fragments.

While traction is maintained, the extremity is rotated internally and is abducted, thereby approximating the fragments. As a rule, the head fragment falls into the position of valgus by this manoeuvre; at times it is necessary to grasp it with a uterine tenaculum and rotate it into its new valgus position. After release of the traction, while the lower extremity is held in abduction and internal rotation, the fragments usually engage sufficiently to allow the insertion of a Smith-Petersen nail without loss of alignment (Fig. 2). If the head tends to rotate after insertion of the nail, it is held in position with a tenaculum. Occasionally a long bony projection is encountered along the inferior aspect of the proximal fragment, which interferes with reposition of the proximal fragment into a position of valgus. To obtain the desired alignment, it may become necessary to remove this bony projection or "beak". This is readily accomplished with a bone biter.

As a rule, no difficulty is encountered in dealing with fractures through the middle of the neck or the subcapital area. In both of these locations, the distal fragment is always long enough to allow removal of a wedge of bone sufficiently large to provide a good plateau for the capital fragment. However, in some of the long oblique subcapital fractures, the distal cervical segment is too short to allow the removal of a wedge of bone. In these instances, the plateau for the capital fragment is carved out of the intertrochanteric area.

POSTOPERATIVE MANAGEMENT

The first patients in this series were permitted early partial weight-bearing on the fractured extremity. The danger of this was soon evident; now, weight-bearing is not allowed for four and one-half or five months after operation.

OBSERVATIONS REFERABLE TO EARLY BONY UNION

Roentgenograms were taken every six weeks. It was observed that, in all cases in which union occurred, roentgenographic evidence of bony union was present within twelve to sixteen weeks after operation. In one case aseptic necrosis of the head was observed three months after operation, before bony union was discernible; nevertheless, union did occur by the end of the eighth month.

Key, in 1932, demonstrated that raw surfaces of bone, subjected to constant compression, exhibited rapid osteogenesis. More recently Charnley confirmed this observation and concluded that the effect of compression is impaction of the cancellous surfaces until the opposing trabeculae almost interdigitate. He believed also that compression is responsible for the rise of dynamic forces which promote cellular activity, thereby forming early a bridgehead of osteoid tissue between the adjacent raw bone surfaces. Osteoblasts convert this osteoid bridgehead into bone by utilizing local bone substance, obtained from nearby areas of osteoclasis.

In view of the early evidence of bony union in all the cases in this series in which union occurred, one can assume that the principle of compression and its effect are applicable to these cases. The compression forces are provided by the powerful iliofemoral muscles, which tend to impact constantly the fracture fragments. These forces are effective even when the capital fragment demonstrates evidence of partial or total vascular occlusion, as illustrated by the case in which aseptic necrosis of the head was exhibited before the advent of bony union.

FIG. 4-A

Fracture of the neck of the femur with minimal displacement, although the fracture line is almost in the vertical plane. (The author feels that these fractures demand internal fixation, because absorption at the fracture line may produce displacement of the capital fragment. Such a complication occurred in two instances in which no internal fixation was used. Impacted fractures with the head in a position of valgus need, as a rule, no internal fixation.)

FIG. 4-B

FIG. 4-C

Fig. 4-B: Roentgenogram immediately following operation shows valgus position of the head fragment after removal of a wedge of bone from the proximal fragment. This nail has penetrated the articular surface of the femoral head.

Fig. 4-C: Roentgenogram thirty months after operation. Note solid bony union and absence of vascular complications involving the capital fragment. The nail has been removed.

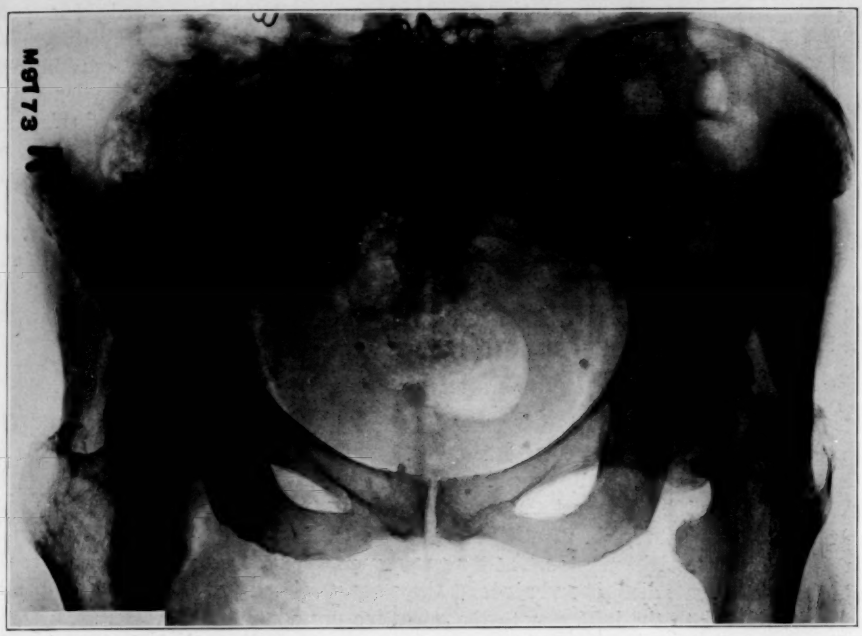

FIG. 5-A

Adduction fracture of the femoral neck.

FIG. 5-B

FIG. 5-C

Fig. 5-B: Roentgenogram immediately after operation showing the capital fragment in a position of valgus.

Fig. 5-C: Increased density of the head is indicative of impaired vascularity. Union at the fracture site was delayed, but finally was demonstrable roentgenographically eight months after operation. Some absorption of the neck occurred.

OTHER SIGNIFICANT OBSERVATIONS

Adequate reposition of the fragments by the various accepted manoeuvres was difficult to attain in some of the reported cases and impossible in others. The bony projection

on the inferior aspect of the proximal fragment, in several cases, was wedged into the substance of the distal fragment in such a fashion that no amount of manoeuvering would disengage it without the use of tremendous force, which would inflict great crushing and comminution upon the distal cervical segment. One can readily conceive the dangers of forceful manipulation, both to the bone substance and to the blood supply of this area.

In two cases not included in this series, in which a transcervical wedge osteotomy had been performed, it was impossible to penetrate the femoral head with a Smith-Petersen nail. In both instances primary arthroplasty had to be resorted to. After the operation the femoral heads were placed upon a wooden block and an attempt was made to drive in a three-flanged nail. In one instance the end of the nail splintered, but did not penetrate the head; in the other, the head disintegrated into several fragments, but did not allow penetration of the nail. Thus it may be possible that, in a small number of cases, the increased density of the head prohibits any type of internal fixation.

ANALYSIS OF CASES

Forty cases of transcervical fractures, conforming to Pauwels' Types II and III, are presented. In all but one case there was adduction displacement of the capital fragment. The ages of the patients ranged from sixty-two to ninety-seven years. In twenty-two of these cases the interval since operation is more than eighteen months, ranging from eighteen to twenty-six months; in sixteen cases the interval is over six months, ranging from six to eight months. There were no operative deaths or deaths related to the injury. Two patients died six and nine months, respectively, after the injury; their deaths were not related to the injury or to the operative procedure. In all instances a transcervical wedge osteotomy, as previously described, was performed. In determining the percentage of non-union, all cases in which the interval was over six months were considered. There were four instances of non-union (10 per cent.). The percentage of aseptic necrosis was based upon the number of cases in which an interval of eighteen months or more had elapsed since operation. There were four instances of aseptic necrosis among twenty-two such cases (18.1 per cent.). Aseptic necrosis was demonstrable in one case during the third month after operation, before bony union took place; in the other three cases it was observed in the sixth, ninth, and seventeenth months, respectively. In all instances in which bony union was obtained, roentgenographic evidence of union was demonstrable between the twelfth and sixteenth week after operation. This is exclusive of the case in which aseptic necrosis of the femoral head occurred prior to bony union; in this instance union was not evident until the eighth postoperative month. Although it is difficult to determine the absence or presence of bony union by roentgenograms, nevertheless the following features were believed significant and were regarded as the criteria by which bony union was considered to be present: (1) the lack of roentgenographic evidence of absorption at each side of the fracture line, and (2) the presence of bony trabeculations across the fracture line, demonstrable by examination of stereoscopic roentgenograms.

Study of the causes for non-union in the four cases reported in this series disclosed that three of the individuals insisted upon early weight-bearing, in spite of repeated warnings. In the other case, non-union can be attributed to poor surgical technique.

SUMMARY AND CONCLUSIONS

Wedge osteotomy through the neck of the femur is offered as a simple and effective procedure for converting sheering forces at the fracture site into compression forces. Adequate reposition of the fragments and proper nailing may not be sufficient to neutralize the effects of powerful sheering strains. The conversion of sheering forces to impacting forces at the fracture line by placing the head of the femur in a position of valgus favors early union and tends to reduce the incidence of non-union. The lower incidence

of aseptic necrosis may be due to the rapid healing process that takes place at the fracture site when the femoral head is placed and fixed in a position of valgus; this process may save many femoral heads when their vascular status is impaired by the injury. It is readily

FIG. 6-A

Typical adduction fracture.

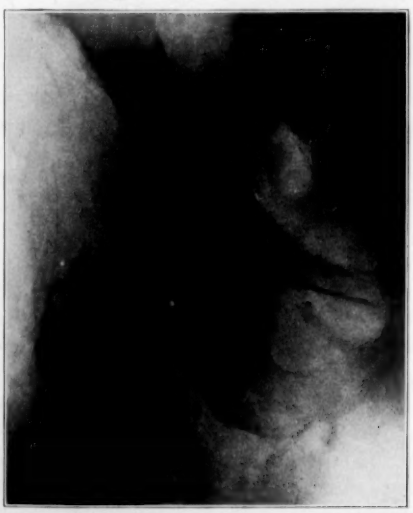

FIG. 6-B

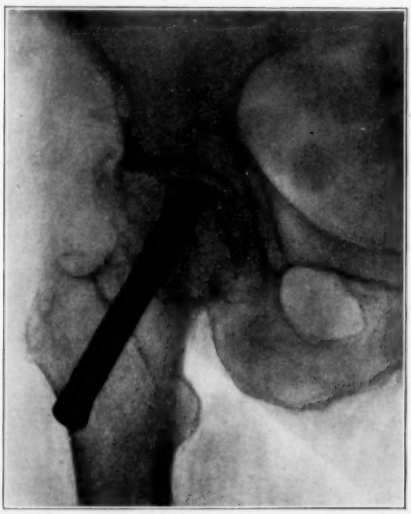

FIG. 6-C

Fig. 6-B: Roentgenogram immediately after operation. Note valgus position of the head.
Fig. 6-C: Roentgenogram taken thirty-two months after operation. Note complete bony union and absence of vascular complications involving the capital fragment.

conceivable that such an active reparative process may play a major role in supplying sufficient nutrition to a capital fragment, thereby precluding the sequelae of diminished or occluded blood supply. However, longer follow-up studies are necessary before the final incidence of capital necrosis can be established.

It is apparent from this study that open reduction does not increase the rate of mortality or the postoperative complications, nor does it increase the incidence of nonunion or aseptic necrosis. Open procedures permit adequate visualization of the fracture site; and a transcervical wedge osteotomy allows reposition of the fragments in the desired alignment without resorting to forceful, damaging manoeuvres.

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LEGG-PERTHES DISEASE

A Method of Conservative Treatment *

BY MAURICE M. PIKE, M.D., HARTFORD, CONNECTICUT

In 1940, at the Newington Home and Hospital for Crippled Children, a preliminary report [7] on a method of treatment for Legg-Perthes disease was presented, with the results of ten cases followed for four and one-half years. A total of fifty-nine patients are now being treated, many of whom have been followed from eight to twelve years. The end results will be evaluated in this paper. We shall make no effort to discuss the pathological aspects of this condition, which have been covered in other papers.

Our method consists of enforced recumbency, carried out over a prolonged period of time until the entire stage of regeneration of the head is completed, as shown by roentgenogram. Our interest in this condition was stimulated by the work of Danforth, who obtained satisfactory results with conservative treatment. Our feeling was that complete avoidance of weight-bearing was essential to allow the head of the femur to assume a natural and normal state or one approaching normal.

It has been noted by Ferguson and Howorth, Steele, and others, that at operation the articular surface of the cartilage is round and apparently smooth, a finding which one would hardly suspect from the roentgenographic evidence. It is considered essential to maintain the shape of the head of the femur as nearly normal as possible, thus avoiding a poorly shaped head or acetabulum. Relatively incomplete cooperation was obtained from children of this age group in refraining from weight-bearing, even though they were kept in bed. Therefore, some type of apparatus seemed necessary. Many of the children climbed to their knees which, of course, produced weight-bearing on their hips; we felt this was inadvisable. Many methods of ambulatory treatment have been suggested, such as a patten-bottom ischial weight-bearing splint; splints with an elevated shoe on the opposite side, which prevent weight-bearing; and a leg sling, as described by Snyder. These methods are inadequate, since the child cannot be trusted to refrain completely from weight-bearing, twenty-four hours a day.

The Wu splint, used originally as a means of maintaining reduction in cases of congenital dislocation of the hip after manipulation, was modified. For our use the extremes of abduction were not necessary, and a splint was made to include the torso and extend below the knee, with or without a foot piece (Figs. 1-A and 1-B). This is an effective means of preventing weight-bearing. The child wears the splint night and day, and is able to turn in bed without difficulty.

At the time of admission to the Hospital, Buck's extension is applied to relieve muscle spasm and to reduce any deformity which may be present. While in bed, the patient receives training to maintain muscle tone. The child is measured at once for a splint, which is ready for application in approximately three weeks. That length of time is necessary to reduce all muscle spasm and deformity before the splint is applied. The child is placed on a Bradford type of frame and, in a very short time, he is able to turn from the supine to the prone position and back again without difficulty. Nursing care is very easy. The physical-therapy department provides supervised exercises for all extremities, as well as underwater exercises. The active exercise is indispensable. It maintains muscle tone, lessens atrophy, and helps to preserve normal joint motion. Periodic roentgenograms are taken to note the progress of the disease. During the first year of recumbency, roentgenograms are usually taken at three-month intervals; after that, at six-month intervals.

* Read at the Annual Meeting of The American Academy of Orthopaedic Surgeons, Chicago, Illinois, January 27, 1948.

An advantage of treating such patients in an institution is that school may be continued throughout the period of recumbency. In our experience, recumbency has been enforced for periods of from one to a maximum of five years. Treatment is, therefore, continued until complete regeneration of the structures of the affected hip is visualized by roentgenogram. A number of bilateral cases have been treated, and in at least one instance we have had the benefit of observing the entire course of changes in the second hip during the period of recumbency. In the second hip, all phases of degeneration and regeneration developed at a much more rapid pace than was observed in the other hips in which the process began under the conditions of stress of normal physical activity.

FIG. 1-A

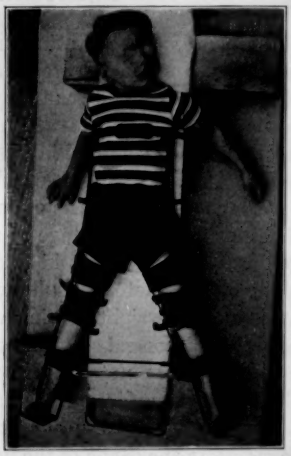

FIG. 1-B

Child in Wu splint.

Treatment has been completed in forty of the fifty-nine cases; nineteen patients are still being treated. Eleven cases were treated by other methods, not described here; twenty-nine cases have been treated by this method (Table I). The shortest period of follow-up in this group of patients is three years and the longest is twelve.

Forty-seven of the patients were males and twelve were females,—a ratio of four to one. The youngest child was two and one-half years of age and the oldest was fifteen years. Twenty-five had involvement of the right hip; twenty-three, of the left. Eleven or 18 per cent. showed bilateral involvement.

Duration of Symptoms: The earliest case was first seen two weeks after onset and the latest forty-eight months after onset; the greatest number of patients, particularly in the earlier part of the series, were seen between six and eight months after onset. The presenting symptoms were limp in all of the cases and pain—usually referred to the knee, as noted by Gill [4]—in nearly all. Trauma was mentioned frequently.

Physical Findings

1. *Motion* in nearly all directions was restricted in all cases at the time of admission.
2. *Atrophy* was recorded in nearly all cases.
3. *Shortening* was present in thirteen, absent in forty-four, and not recorded in two.

Roentgenograms have shown the typical cycle of degeneration and regeneration, as reported by Brailsford. He stated that "for upwards of four years . . . the bone of the affected joint was plastic and could be deformed by pressure". From these observations he developed a "time table".

Gill [4] also mentioned this finding, indicating that the degenerative stage progressed for approximately eighteen months, and another year and one-half to four years were required for regeneration. Other roentgenographic observations have been made by Ferguson and Howorth.

FIG. 2-A

FIG. 2-B

Fig. 2-A: E. M. Admission roentgenogram, in 1939. Limp and pain had been present in right hip for four weeks. Note narrowing and irregularity of right femoral head with some broadening of neck.

Fig. 2-B: Appearance in 1940, after one year of enforced recumbency. Note fragmentation of right femoral head. Acetabulum appeared normal.

FIG. 2-C

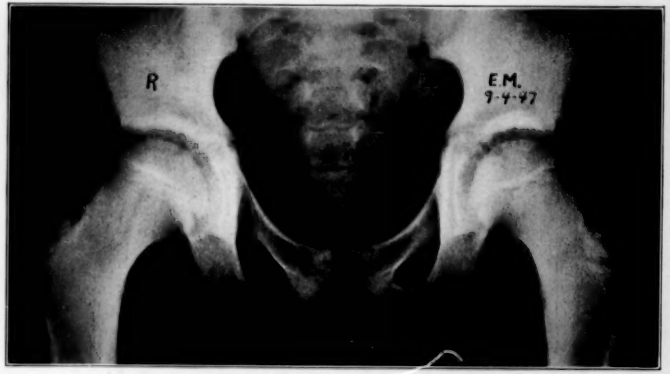

FIG. 2-D

Fig. 2-C: Appearance in 1941, after one and one-half years of recumbency. There was fragmentation, and regeneration and recalcification were occurring.

Fig. 2-D: Anteroposterior roentgenogram in 1947, eight years after admission. There was complete regeneration of the right femoral head, with a normal-appearing acetabulum and femoral neck. The clinical and roentgenographic result was considered excellent.

TABLE I

LOCATION OF LESION AND METHOD OF TREATMENT IN FIFTY-NINE CASES

Method	No. of Cases	Hip Involved	No. of Cases
Miscellaneous. No splinting. Treatment completed.	11	Right	25
Splinting. Treatment completed	29	Left	23
Splinting. Treatment being continued	19	Bilateral	11
Total	59		59

The average hospital stay in these cases was twenty-eight months; the average length of recumbency was twenty-seven months.

Laboratory findings were inconclusive. Confirming Gill's studies [5], we found no relationship to hypothyroidism. The sedimentation rate was nearly always normal; any elevation could usually be attributed to other causes.

In classifying the end results, the authors have used essentially the criteria presented by Levy and Girard,—namely, height of the head as shown by roentgenogram, range of motion in the hip as shown by clinical examination, shortening, and the presence or absence of pain. The percentage of excellent or good results in the patients treated by recumbency is 83 as compared with 36 per cent. in the miscellaneous group (Table II).

Throughout this period of observation (from three to twelve years), our constant desire has been to provide complete and normal development for these children, both physically and mentally, while weight-bearing on the hips is prevented. The percentage of bilateral involvement is nearly 20, which indicates that in the early stages of treatment, weight-bearing for both extremities should be completely avoided, because of the likelihood of the opposite or apparently unaffected side becoming involved. Close observation has been found necessary to determine possible involvement of the opposite side.

These children have lost no time from school, as educational facilities are available through high school. Physically we believe that they have grown at a rate equal to that of apparently normal children. The daily physical therapy includes the whole body and

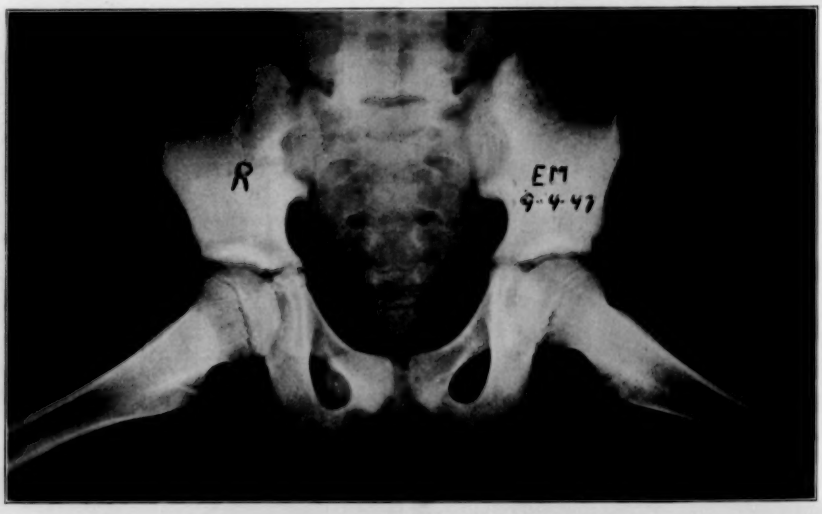

FIG. 2-E

Lateral roentgenogram in 1947.

is not confined to the affected extremities. This keeps the circulation adequate and ensures satisfactory muscle use, so that no retardation of general development is apparent. Of the forty-eight cases treated by this method, there was no shortening in thirty-eight and less than one centimeter in ten. With regard to atrophy, five had no record of measurement in the early stages of treatment; seven showed atrophy of the thigh and calf of approximately one-half inch; the other thirty-six showed no atrophy or inequality in the circumference of the legs at the time they were discharged from the Hospital. Roentgenographic evidence has shown no generalized loss of lime from the bones, to suggest any widespread bone atrophy. Thus constant effort has been directed toward maintaining activity as nearly normal as possible, with the sole exception of avoidance of weight-bearing. It is our belief that this program will allow these children to grow and develop normally.

TABLE II

END RESULTS OF TREATMENT WITH AND WITHOUT SPLINTS

Result	Without Splints		With Splints	
	No. of Cases	Per cent.	No. of Cases	Per cent.
Excellent	1	36	10	83
Good	3		14	
Fair	3	64	3	17
Poor	3		1	
Unclassified	1		1	
Total	11	100	29	100

A typical case is described:

E. M., a boy of four, entered the Hospital on September 5, 1939, complaining of a limp and pain in the right hip of four weeks' duration (Fig. 2-A). There was no shortening or atrophy and the only motion restricted was abduction. The roentgenographic appearance of the hip is shown in 1940 (Fig. 2-B), in 1941 (Fig. 2-C), and in September 1947, eight years after admission (Figs. 2-D and 2-E). The boy was recumbent for thirty-four months and in the Hospital for thirty-nine months. At the age of twelve there was no shortening or atrophy, a full range of motion, and no symptoms. His activities are unrestricted and follow-up will be continued.

In one bilateral case, the entire process in the second hip occurred during the period of recumbency.

N. J., a boy, began to have symptoms of pain in the left knee with a left-sided limp in March 1942, at the age of two years and eleven months. Recumbency was begun on June 10, 1942, when flexion and adduction contracture was noted (Figs. 3-A and 3-B). No atrophy or shortening was present. On March 1, 1943, after nine months of bed rest, changes were first noted in the right hip (Figs. 3-C and 3-D). The entire cycle was much more rapid in the right hip than in the left. The maximum amount of degeneration in the left hip was reached in seventeen months, while complete regeneration required an additional forty-five months or a total of sixty-two months. In the right hip maximum degeneration was reached in twenty months, only twenty-three additional months being required for complete regeneration or a total of forty-three months. Figures 3-E and 3-F show the appearance in 1945. This patient was kept in enforced recumbency for exactly five years. Roentgenograms in October 1947, after three months of weight-bearing (Figs. 3-G and 3-H), show that the right hip is more normal in appearance, with a better shaped head, more normal epiphyseal line, and a narrower or more normal neck. This is a strong point in favor of complete avoidance of weight-bearing.

CONCLUSIONS

1. Prolonged avoidance of weight-bearing offers the best opportunity for near-normal restoration of the bone structure of the hip in Legg-Perthes disease.

2. Enforced recumbency is the best method of ensuring this result.

3. This treatment may best be carried out in an institution, where schooling, physical therapy, and medical care are constantly available.

NOTE: The results presented here represent the combined work of the Staff of the Newington Home and Hospital for Crippled Children.

FIG. 3-A

FIG. 3-B

N. J. Admission roentgenograms in 1942, showing narrowing and irregularity of left femoral head. Symptoms had been present for three months on left.

FIG. 3-C

FIG. 3-D

In 1943, one year after admission, there was marked degeneration and fragmentation of left femoral head and widening of neck, with less marked fragmentation and degeneration of right femoral head. Widening of neck can be seen on both sides. Symptoms were never present on the right.

FIG. 3-E

FIG. 3-F

Appearance in 1945, three years after admission, showing complete regeneration of right (second) femoral head and some widening of neck. Acetabulum appeared normal. On the left, regeneration was still incomplete; and definite irregularity may be noted in the acetabulum.

FIG. 3-G

FIG. 3-H

Roentgenograms taken in 1947, five years after admission, showing complete regeneration of both femoral heads with some narrowing and lateral spread of left femoral head.

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DISCUSSION

Dr. M. Beckett Howorth, New York, N. Y.: I have not had the opportunity of seeing Dr. Pike's patients, and have seen the films of only twelve of them. Therefore, I am not qualified to judge the results. His method is perhaps the best way of keeping weight off the hip. The results in his twelve cases are good, but healing took a long time, and treatment was begun months or years after the onset of the disease. The results are as good as any of our results with non-weight-bearing and the time of recovery is comparable, although Pike keeps the children recumbent longer than we do. Traction is helpful in relieving pain and spasm in the first few weeks of treatment. However, his splint immobilizes the hip in extension for the greater part of the day. We believe that the degenerative changes in coxa plana are due to a disturbance in the blood supply to the capital epiphysis. This blood supply is diminished or wrung out by the twisting of the soft tissues in the extended position, whereas the vessels are free in flexion, so that a position of at least slight flexion is preferable. Immobilization also impairs the circulation. Therefore, it is preferable to allow motion much of the day. The ideal treatment is suspension in some flexion, free motion in bed, or suspension in a sling when the child is ambulatory. We have used a sling and crutches for more than ten years and the results have been good, but also take a long time.

Dr. Pike showed a case with bilateral involvement, stating that the disease developed and ran its course during the period of recumbency. [See Figs. 3-C and 3-D.] However, there appear to be definite changes of coxa plana in the film of June 1942, before the period of recumbency. If these nine or more months are added to the forty-three months after March 1943, making a total of fifty-two months, there is no more variation in the duration of the disease in the two hips than is seen in many other cases. Further, one can draw no comparative conclusions from any one or two cases.

Our best results were obtained in less time in the group treated by the drilling operation, combined with non-weight-bearing. We can probably prevent coxa plana by putting at rest all hips with synovitis in this age group, before the changes in the capital epiphysis develop.

None of us yet knows the direct cause of coxa plana, its prevention, or a prompt and effective cure. Treatment of this disease should not require several years. Our work should be directed toward discovering how to prevent coxa plana, or at least how to cure it in a matter of weeks rather than of years.

Dr. A. Bruce Gill, Philadelphia, Pennsylvania: Treatment by non-weight-bearing, if begun before collapse of the head and the neck has occurred, will result in a normal hip after regeneration. If treatment is begun when the degenerative phase is well advanced, there will be some residual deformity, its severity depending on the degree of crushing which the head and neck have sustained. Dr. Pike's bilateral case, in which the disease of the right hip developed during recumbency, well illustrates the facts that early treatment shortens the time cycle of degeneration and regeneration and results in a hip which more closely approaches normal.

Unfortunately, the orthopaedic surgeon does not see these cases until weeks or months after the onset of symptoms. The early symptoms of limp and pain, usually in the region of the knee, are frequently slight and are relieved by a few days of rest. Consequently, they may escape observation by the parents or be neglected until the condition has become more serious; the true condition may not be diagnosed by the physician because he can find nothing the matter with the knee and because the symptoms so readily disappear as a result of rest. Even when the orthopaedic surgeon sees these patients after symptoms have been

(*Continued on page 676*)

RECESSION OF THE GASTROCNEMIUS

An Operation to Relieve Spastic Contracture of the Calf Muscles*

BY LUTHER M. STRAYER, JR., M.D., BRIDGEPORT, CONNECTICUT

Tenotomy of the tendo achillis is one of the oldest procedures in the surgical heritage of orthopaedic surgery. In 1816, Delpech performed the first subcutaneous section of the tendo achillis for club-foot. Before this time the operation had been done by the method of open incisions. Garrison stated that Stromeyer repeated this subcutaneous tenotomy in 1831. Jones stated that William Little, who had talipes equinovarus resulting from infantile paralysis, studied with Stromeyer, who divided his tendo achillis. Little was, thereafter, at once a demonstration of his successful result and the chief practitioner of subcutaneous tenotomy. He came to America in 1878, where he met Detmold, a pupil of Stromeyer, who was orthopaedic surgeon to the Bellevue Hospital and who had introduced subcutaneous tenotomy to America.

Many variations of tenotomy of the tendo achillis have been devised since the development of aseptic surgery and the change to the open method. However, not even these variations were adequate in cerebral palsy. Stoffel outlined a method of denervating spastic muscles. An important point in his operative technique was the use of sterile stimulating electrodes, by which he could determine which nerves to sever in order to reduce the resistance of these muscles to stretching.

The author's impression, gained from examining patients who have had heel-cord lengthening and the Stoffel procedure, has been one of disappointment. This feeling has been shared by others, but there seemed no alternative except the use of triple arthrodesis as a means of controlling the equinus. However, in small children the equinus is sometimes extremely persistent, and the spasticity prevents normal gait until the child is old enough for a triple arthrodesis to be done.

The philosophical background of the procedure suggested in this paper was gained while reading *Mechanics of Normal and Pathological Locomotion in Man*, written by Steindler in 1935, and the possibility of separating the calf muscles into two elements was formulated. The history and details of the classification of biarticular muscles are thoroughly discussed by Steindler.

While treating extensive war wounds, the author noticed that the insertion of the heads of the gastrocnemius into the aponeurosis of the soleus is quite susceptible to surgical approach. It was, therefore, considered possible to diminish the pull of the gastrocnemius by severing and reattaching this insertion at a higher level, without interfering with the mass of the tendo achillis or the nerve supply of the gastrocnemius. Another thought was that, if re-education was successful, the area might be approached again and the leverage of the gastrocnemius increased, with full knowledge that some power might be developed from the undenervated gastrocnemius.

The usefulness of this procedure was demonstrated in Case 1 of the series, when it was found that, with the knee in 90 degrees of flexion, the foot could easily be dorsiflexed to 90 degrees. This demonstrated that severance of the gastrocnemius from the soleus would allow the patient to place his heels on the floor when walking.

Since beginning this work, it has been discovered that Silfverskiöld presented a paper on this subject in 1923. This author, with exactly the same philosophical background and reasoning, approached the problem by separating the heads of the gastrocnemius from their origin on the femur. It is evident from his case reports that this was difficult and

* Based on film presented at Audio-Visual Education Program, The American Academy of Orthopaedic Surgeons, New York, N. Y., February 12, 1950.

sometimes resulted in knee effusion. He presented two cases with satisfactory results, one in which the principle was used on the gastrocnemius, and another in which it was used on the rectus femoris and the hamstring muscles.

The eight cases, reported in detail here, all resulted in the patient being able to place his heels on the ground during weight-bearing.

OPERATIVE PROCEDURE

The operation has been performed through a curved four-inch to six-inch incision over the middle of the calf posteriorly. The sural nerve should be retracted. The deep fascial compartment of the gastrocnemius is opened and, by blunt dissection, the separation of the muscles from the soleus beneath is carried down to the point where the tendons of the gastrocnemii enter the common tendon with the soleus. The gastrocnemius tendon is then severed over a probe. If the foot is then dorsiflexed, a gap of from three-fourths of an inch to an inch will appear between the ends of the severed tendon. It is the author's practice to lift the proximal portion of the tendon and to dissect the body of the gastrocnemius from its attachments to the deep fascia at both the medial and lateral aspects of its muscle compartment. This allows slightly more retraction of the muscle. In the oldest patient operated upon (aged thirteen), these lateral attachments were much firmer and more restrictive than in the younger patients. The severed tendon is then tacked to the soleus with fine silk sutures, at least an inch higher than its original attachment.

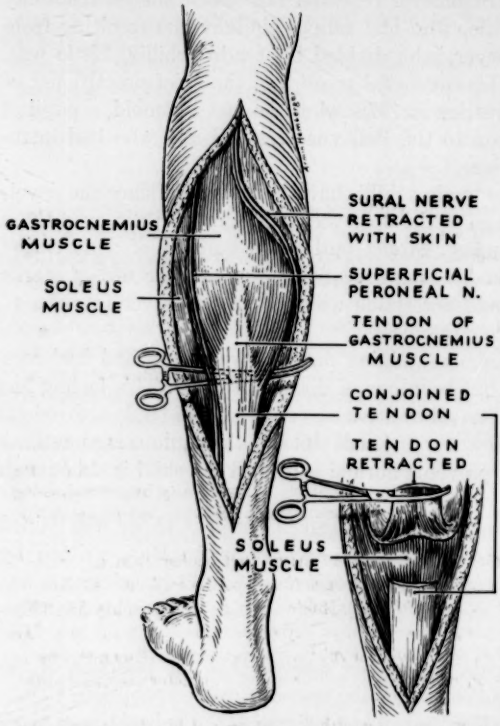

FIG. 1

In the oldest patient, who had previously had a Stoffel operation, the sural nerve became extremely tense when the foot was dorsiflexed, and it was necessary to stretch it gradually. Hyperaesthesia of the sole of one foot also developed in this patient. In none of the younger patients did the nerve become tight, nor was there any interference with sensation.

The wounds are closed with subcuticular catgut sutures, so that the original casts need not be removed. Great care is taken postoperatively to apply a smooth toe-to-groin cast on each lower extremity, with spreader bars attached to the knees and the feet to maintain abduction. The feet are placed at 90 degrees of flexion. These casts are allowed to remain in position for four weeks, after which they are used as night splints until the muscles have regained their tone.

While the patient is in the cast, intensive exercises for gluteal development are given. Previously these patients had had almost no ability to use their gluteal muscles in standing.

CASE REPORTS

CASE 1. D. G., a boy, was born on April 2, 1945. No abnormality had been noted at birth. A twin died

immediately after birth. The patient sat up at twelve months; at fourteen months it was noted that he turned his left foot inward. He was admitted to the Crippled Children's Clinic on April 3, 1947. During the first examination tight adductors, internal rotators, and hamstrings were reported; spasticity was noted, especially in the left leg. There was lordosis and stiffness of the lumbar spine. Stretching and muscle education were carried out for a year without essential change.

The boy was first seen by the author on February 6, 1948, at the age of three. He could walk on tiptoe with assistance. Occasionally he attempted to walk alone, but he would fall and be unable to arise to his toes. He had a fear of walking without assistance. Examination showed an active boy, who walked on tiptoes with knees flexed; his left foot passed into 25 degrees of internal rotation during weight-bearing. There was a tendency to rocker-foot deformity, and the heel cords were extremely tight. No spasticity of the adductors, flexors, or hamstrings was noted. Reflexes were normal. There was no evidence of meningocele. The condition was diagnosed by a pediatrician and a neurologist as cerebral palsy. Pseudohypertrophic muscular dystrophy was considered by the author.

Bilateral recession of the gastrocnemius was performed on April 6, 1948. Now the child walks freely and runs up and down the sidewalk in front of his house, which he had never done before. He accepts the normal responsibility for moving himself, instead of being carried.

Postoperative examination showed a flat-footed, somewhat calcaneus gait with hyperextension of the knees and marked correction of the lordosis. The contour of the calf was good; voluntary control of the anterior tibial muscle was positive. The internal rotators of the left leg remained, but the patient could walk on tiptoe voluntarily.

CASE 2. J. A., a boy, was born on August 25, 1937. The child was twelve months old before abnormality was noted; a diagnosis of birth injury was made. He was admitted to the Crippled Children's Clinic in May 1942. Physical examination showed marked spasticity of both legs, scissor gait, and marked valgus of the feet. By 1943 the patient had learned to walk with crutches, although the adductor spasm, flexion of the knees and hips, and tight heel cords remained.

In 1944, a triple arthrodesis, tenotomy of the left heel cord, and tenotomy of both adductor tendons were carried out. Postoperatively the heel cords remained corrected, but flexion of the knees and adductor spasm destroyed the effect of the operation. In 1946, triple arthrodesis and heel-cord lengthening were performed on the right. The patient continued to do fairly well, but still had tight adductors and tight heel cords. A Stoffel operation and bilateral adductor myotomy were considered at this time.

In July 1948, bilateral recession of the gastrocnemius was done. Postoperatively the patient walked much better. His feet were flat on the floor and he showed no tendency toward scissor gait. His mother reported that he was able to go to the bathroom alone. He climbed two flights of stairs daily by himself, using crutches. He could stand straighter and was able to flex his knees and ankles to put on shoes and stockings.

CASE 3. T. A., a boy, was born on October 21, 1936. His mother noticed that his legs were a little stiff at the age of one year, and at the age of fourteen months the doctors noticed that he could not sit up.

He was admitted to the Pediatric Department of the Crippled Children's Clinic on February 23, 1938, and was seen by an orthopaedic surgeon. There was generalized spasticity of the arms, legs, and head. He could not sit, stand, or walk. During this period the patient had convulsive seizures, lasting fifteen to twenty minutes. He was then admitted to another hospital, where heel-cord tenotomies, adductor myotomies, and Stoffel operations were carried out.

In 1946, the patient returned to the Clinic. He was walking with a great deal of hip flexion and knee flexion, and the heel cords were tight. In October 1948, bilateral recession of the gastrocnemius was performed. This patient had a severe emotional upset during the postoperative period. It was necessary to teach him to walk with crutches while the casts were in place. Gradually, however, he quieted down, and the last report from his mother indicated that his whole attitude had changed. He was able to walk with his heels down, his feet farther apart, and his knees separated. He could stand straighter. He was losing his sense of fear, which he had had since falling from a stretcher in a hospital. He was able to go to the bathroom by himself, which he could not do before. He was able to walk more, to go up and down stairs alone without crutches, and to get up from the floor more easily.

CASE 4. M. L., a girl, was born on October 25, 1937. The birth was said to have been normal. She had bowel control at fifteen months, sat without support at sixteen months, and talked at twenty-two months.

The child was admitted to Danbury Crippled Children's Clinic on September 28, 1939. Physical examination showed a well developed and nourished girl with internal strabismus on the left. The upper extremities were normal, but the hips and legs were stiff. When held in the standing position, she stood on her toes, leaned backward, and screamed, but could not bear weight. Both feet had complete plantar flexion, even the left, unless the knees were bent. The reflexes were exaggerated; the Babinski sign was present bilaterally.

On December 10, 1940, a bilateral Stoffel operation was performed on the gastrocnemii. Afterward the

child continued to walk on her toes, although weight could be placed on the heels when she was standing.

On October 30, 1942, a triple arthrodesis was done on the left; and, on June 19, 1944, a triple arthrodesis on the right. After these procedures the patient continued to walk, but with flexion in the knees and hips and internal rotation of the hips. She was unable to get her heels onto the floor. Braces were tried without success; prostigmine was also unsuccessful. The child's intelligence quotient was believed to be normal.

Bilateral recession of the gastrocnemius was carried out on October 27, 1948. The patient was left in abduction casts for about five weeks, and they were used as night casts for another two months. On April 23, 1949, bilateral toe-to-groin casts were applied and the patient was allowed to walk with crutches. The casts were removed on July 5, 1949, when the child was able to walk without shoes. There was complete extension of both knees. She could bend and straighten her knees alternately, with enough power in the quadriceps to counteract her own weight. The heel cords were relaxed enough to allow dorsiflexion to 90 degrees, when she was seated in a chair with her knees straight.

The mother reports that, since the operation, the patient can go to the bathroom by herself. She is able to set the table and clear it. She can get in and out of a car almost unaided. She is willing to walk a great deal more out of doors than she did, and her whole attitude has become more enthusiastic.

CASE 5. V. S., a boy, was born on June 15, 1943. The birth history is said to have been normal. He sat up at two years, but never walked. Simple one-syllable or two-syllable words were spoken. Bowel and urine control was not certain.

The child was admitted to the Crippled Children's Clinic on June 14, 1946. Physical examination, as recorded on July 29, 1947, showed a grossly undernourished child. He held both lower extremities flexed at the hip and the knee. He cried easily and was easily frightened. When he sat on the edge of a table, his legs hung down and the feet were plantar-flexed. The arms were held in slight abduction at the shoulder and in flexion at the elbow. He grasped poorly, but was able to do so when objects were placed in his hand. The Babinski was present bilaterally. When the feet were placed on the floor and the patient was supported beneath the arms, he stood on his toes and was unable to place the heels down. The adductors and hamstrings were tight, but attempts to walk produced marked "scissoring" of the legs.

The patient was fitted with long-leg braces, but "scissoring" still tended to occur and the heels could not be held down in the shoes.

On March 2, 1949, bilateral recession of the gastrocnemius was performed. Following operation the patient had a severe emotional upset, being terrified and crying continuously when handled, when wearing his braces, and during attempts to walk. At times this crying appeared to be due to pain; at other times it would stop quickly, even though the environment was the same and handling was continued. He was sent to another hospital for a month and was much quieter when he returned. At that time he showed more co-ordination when assisted in walking. The legs did not cross. The heels were at the soles of his shoes at all times, and he was beginning to enter into activities with other children more freely.

CASE 6. J. D., a boy, was born April 20, 1939. He weighed three pounds at birth. At the age of two, he could not walk. Examination of the brain was negative.

The child was admitted to the Crippled Children's Clinic on November 25, 1941. Physical examination showed a well developed and nourished child who stood with his knees and legs crossed. Reflexes were normal in the right arm and hyperactive in the left. Hoffmann and Babinski signs were present on the left. He walked on his toes with help.

Bilateral tenotomy of the heel cord was carried out on February 3, 1943. Postoperatively the patient walked with flexion of the knees and of the hips. The right heel could be placed on the floor, but the left only after considerable pressure. There was much scuffing of the shoes at the toes.

On March 2, 1949, bilateral recession of the gastrocnemius and shortening of the right heel cord were carried out. (Overcorrection on the right had been obtained by the previous operation.) After operation the patient could place both heels on the floor well, and some voluntary contraction of the anterior tibial muscles was developing. The parents stated that the child could stand straighter and steadier, with more sense of balance. He no longer fell. He was able to run, and he did not scuff his shoes.

CASE 7. C. A. C., a girl, was born on March 8, 1936. Delivery is said to have been normal. The patient started to walk at one year, but fell often and was very awkward. She was admitted to the Crippled Children's Clinic on May 27, 1938, at the age of eighteen months.

The first physical examination showed a well developed and nourished girl who walked on her toes, but occasionally put her heels to the ground. There was some scuffing of the toes. She tended to hyperextend her knees and to flex her hips; she had considerable lordosis and a suggestion of weakness of the abdominal and the gluteal muscles. The reflexes were exaggerated. The Babinski sign was noted bilaterally, and clonus was present on the right.

A bilateral Stoffel operation was performed on July 22, 1938.

At physical examination in 1943, the patient walked with an awkward, spastic gait, hyperextending her

knees and hips. There was marked lordosis and a prominent abdomen. There was still tightness of both heel cords. In 1947, foot plates were made, and much pain and foot strain were relieved.

Bilateral recession of the gastrocnemius was performed on April 12, 1949. Casts were allowed to remain in position for a month, after which they were used as night splints. Physical therapy, with development of the abdominal and gluteal muscles, was carried on, and the patient has continued to be able to place her heels on the floor. The anterior tibial muscle functions in both feet voluntarily. There has been no tendency for the adductor spasm to recur. There is some hyperaesthesia of the skin on the sole of the right foot.

CASE 8.* K. K., a girl, was first seen on May 21, 1948, at the age of two and one-half. She had been born prematurely by Caesarian section, but no gross abnormality was detected until she began to walk at the age of fifteen months, when it was noted that she "favored" the left leg. Roentgenograms were taken elsewhere, and her physician applied a wedge to her shoe. In spite of this she failed to improve, and her mother stated that she still did not put her heel to the floor properly.

Examination disclosed that she tended to walk on her toes. The heel of the right foot could, however, be placed directly on the floor without difficulty, whereas the left heel remained elevated, even with weight-bearing, and there was definite shortening of the calf muscles. The thigh muscles were unaffected. Knee and ankle jerks in both lower extremities were present, but were equally hard to elicit. Certainly they were not exaggerated, and no real spasticity could be found except possibly a slight amount in the left calf muscles.

On June 6, she was operated upon by the technique described, and the extremity was immobilized in a cast until July 18. A check-up, two months later, showed that she walked much better than before and was able to place her heel flat on the floor without difficulty. A slight limp from weakness persisted, but in general her gait was much improved. No increase in atrophy of the calf, as is expected after heel-cord lengthening, could be detected.

DISCUSSION

The immediate operative result desired has been obtained in all cases so far treated. The side effects have led to much greater clinical improvement than had been expected from the procedure. The first striking ancillary effect was marked relaxation of adductor spasm. Some of these patients had had previous adductor myotomies and neurectomies, casts, of course, having been applied with the limb in abduction. After these procedures, however, there had been considerable recurrence of adductor spasm. Following the author's operation, the relaxation of the scissor gait was marked. In similar fashion these patients were able to use their gluteii and to contract them while in the standing position, which they had not been able to do before.

There is perhaps a sound neurological explanation for these side effects. The gastrocnemius, having been freed of tension on its fibers as the result of the operative procedure, fails to send to the central nervous system the proprioceptive impulses of tension which had previously been a part of the tonal spinal reflexes; and this may modify fundamentally the extensor spasm reflex which is present on stimulation of the feet by weight-bearing. This change in the tonal reflex of these muscles is so fundamental that the patients recover active use and active dorsiflexion of the foot by means of the anterior tibial muscles, which had usually escaped attempts at voluntary control previously.

The experimental physiology underlying these side effects has already been studied. Fulton[2, 3] discussed the stretch reflex in relation to the tone of muscle in a number of animal experiments. Magnus reported a study of the righting reflexes in animals, decerebrated at various levels, and in man. The most important paragraphs in this work concern the "positive supporting reaction" and the "negative supporting reaction".

By removing from the gastrocnemius both the stimulator and the effector side of the stretch reflex, the author has altered fundamentally the nature of the proprioceptive reflexes as they are set up in the segments of the spinal cord. By dissociating the uniarticular (soleus) from the biarticular (gastrocnemius) muscles, the basic reflex response has been changed in the extremities of these children.

A great deal more work remains to be done in using this principle of reflex physiology in the various aspects of spastic contracture. We believe that it opens a new field of clinical work and that this procedure deserves a place in the surgery of cerebral palsy.

* Summary supplied by A. S. Griswold, M. D., Chief Orthopaedic Surgeon, Bridgeport Hospital.

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DISCUSSION

Legg-Perthes Disease

(*Continued from page 670*)

noticeable for only a few weeks, the pathological process may be far advanced. However, it is remarkable how closely the hip will finally approach to the normal as a result of this method of treatment.

I agree with the author that prolonged recumbency in bed is the most effective method of preventing weight-bearing. Ambulatory treatment with splints, braces, and crutches may not prevent a child from putting at least partial weight on the hip at some time during the day.

This treatment, as the author states, is best carried out in an institution, but it can be done at home very efficiently under the direction of intelligent and careful parents.

The method of bed treatment varies. The author uses splints, accompanied by physical therapy and supervised movements. My own custom has been to employ properly applied skin traction with four to six pounds of weight, which overcomes the tension of the hip muscles and permits voluntary motion. I believe that motion of the hip is not detrimental. If the child tries to rise on his knees in spite of the traction apparatus, he is kept recumbent on a Bradford frame. Long-continued application of plaster produces atrophy.

The chief objection to treatment by recumbency is the long period of time that is necessary. I have shortened this time, without harmful effects as far as I have been able to observe, by the use of an extension brace, crutches, and a high shoe on the opposite foot, when the roentgenograms indicate that the process of regeneration is so far advanced that this type of ambulatory treatment will not be detrimental. My criterion is solid recalcification of that portion of the head of the femur which bears weight.

Dr. William T. Green, Boston, Massachusetts: The results which Dr. Pike has shown are excellent. I agree that the treatment is non-operative, but I wonder if placing a child in an institution and keeping him in bed for as long as five years can be considered conservative. I believe there are simpler ways to obtain approximately the same results.

I would like to illustrate a conservative method of treatment which has been used at The Children's Hospital, Boston, for many years with very good results. Avoidance of weight-bearing is essential during the active phase and until healing is sufficient so that weight can be maintained without collapse of the head of the femur. The result depends in large part upon how early the disease is recognized and upon the effectiveness with which weight is avoided. We use a Thomas ring splint with a patten bottom on the side of the lesion, and a shoe with an elevated sole on the opposite side. This sole is ordinarily from two and three-quarters to three inches in height. This allows the child to walk effectively without bearing weight on the involved hip, since the weight is transmitted directly from the ischium to the patten bottom. In order to keep weight off the toe of the shoe, a strap and buckle are attached at the heel; the strap goes down to the top of the patten and is tightened so as to keep the foot at approximately a right angle. The parent and the child must be impressed strongly that no weight whatever must be placed on the foot, and the parent must be taught to take care of the splint. The patient should be seen at regular intervals.

(*Continued on page 712*)

INFANTILE CORTICAL HYPEROSTOSIS

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The recognition by Caffey and Silverman in 1945 and by Smyth, Potter, and Silverman the following year of the syndrome named "infantile cortical hyperostosis" has aroused and renewed interest in bone and soft-tissue diseases of children. Less than thirty cases have been reported up to this time [1, 2, 4-9].

The syndrome is characterized by the appearance of firm, tender, non-pitting, deeply placed soft-tissue swellings without unusual warmth or discoloration, and by cortical hyperostosis in various parts of the skeleton. The mandible and clavicle are affected most frequently; less often, the scapula, ribs, calvarium, and tubular bones of the extremities, including the metatarsals, are involved. With extensive rib involvement, one may find associated pleurisy. The soft-tissue swellings are generally located in the areas of the hyperostoses. However, hyperostoses have been observed roentgenographically without overlying soft-tissue swellings. The latter, in turn, may be observed clinically without roentgenographic evidence of underlying cortical hyperostosis; but, in some cases at least, the hyperostoses may be visualized after a further period of several weeks. Recurrence of the swellings after complete disappearance has also been noted. There is no concomitant regional lymphadenopathy.

In the great majority of patients, the onset has occurred when the infant was under five months of age, with a range from three weeks to twenty months. Recently, Caffey [3] has asserted that the two older patients described by him in 1946 as having infantile cortical hyperostosis actually suffered from excess of vitamin A; he concluded that no true case began after the fourth month of life. Active symptoms may persist from two to nine months, with complete recovery ultimately. An irregular, low-grade fever is present in almost all cases. Many patients exhibit hyperirritability, pseudoparalysis of the extremities, and dysphagia. Moderate anaemia with leukocytosis has been detected in some cases. Examinations of the bone marrow are essentially negative. An increase in serum alkaline phosphatase has occasionally been reported; the serum calcium and phosphorus are normal.

Bacterial and virus studies [1, 8] have shown no indication of such infection. There is no evidence of allergic, toxic, metabolic, or traumatic etiology. The occurrence of a mild upper-respiratory infection prior to the onset of symptoms in many of the cases reported suggests that the cause is infectious, but this is pure speculation.

Even though the prognosis is uniformly favorable, recognition of the syndrome is imperative, because of the severity of other diseases included in the differential diagnosis. The painful extremities, in conjunction with the other symptoms, suggest scurvy, chronic vitamin-A poisoning, poliomyelitis, leukaemia, rheumatic fever, rheumatoid arthritis, or osteomyelitis. The facial swelling may bring to mind epidemic and infectious parotitis, osteomyelitis or neoplasm of the mandible, as well as traumatic injury. In addition, similar cortical thickenings have been described in syphilis, rickets, and chronic vitamin-A poisoning.

The treatment is entirely symptomatic and supportive. Penicillin and sulfonamide preparations have not been shown to be of value.

CASE 1. W. Z., a first-born white male infant, three and one-half months of age, was admitted to the Children's Ward of the Jewish Hospital on December 1, 1948. The present illness had begun about one

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FIG. 1-A

W. Z. Bilateral facial swelling is evident.

month prior to admission, when the mother observed that the baby's cheeks seemed large. If she touched his face, he screamed in pain. When placed in the prone position, he kept his head elevated, apparently because of the tenderness of the jaws. No other areas of tenderness were noted. A mild upper-respiratory infection of several days' duration, with occasional vomiting, had been noted three weeks before admission. Anorexia had been present for the preceding two weeks.

The infant was the product of a normal full-term pregnancy and an uncomplicated labor. He had had impetigo at five days of age, and thrush at three weeks; recovery was prompt from both illnesses and there were no sequelae. Adequate doses of oral vitamin therapy were begun at the age of two weeks. No history of trauma could be elicited. The family history was not contributory.

The physical examination disclosed an irritable, but well nourished and developed, white male infant with marked bilateral swelling of the mandibular regions and cheeks (Fig. 1-A). The swelling was exquisitely tender, non-fluctuant, firm, and without unusual warmth or discoloration. No pitting on pressure was observed. Several spotty, discrete, non-tender anterior cervical nodes were palpable. The rectal temperature at the time of admission was 100 degrees. The remainder of the examination was essentially negative.

Laboratory findings were as follows:

Red blood cells	3,080,000 per cubic millimeter
Hemoglobin	7.8 grams per 100 cubic centimeters
White blood cells	16,000 per cubic millimeter
Polymorphonuclear neutrophils	49 per cent. (90 per cent. filamentous)
Lymphocytes	49 per cent.
Monocytes	2 per cent.
Blood platelets	342,600 per cubic millimeter
Reticulocyte count	0.5 per cent.
Blood chemistry	
Calcium	10.4 milligrams per 100 cubic centimeters
Phosphorus	5.2 milligrams per 100 cubic centimeters
Alkaline phosphatase	10.2 Bodansky units
Total proteins	6.5 grams

Hypochromia and slight anisocytosis of the red blood cells were noted. Repeated urinalyses were negative. Blood Wassermann and Kahn tests were negative. There was no reaction following the intradermal injection of 0.1 cubic centimeter of full-strength purified protein derivative No. 1. Examination of the tibial bone marrow was negative. Blood virus studies at the Virus Research Laboratories of the Children's Hospital were reported as negative. A throat culture revealed *Streptococcus viridans*, *Staphylococcus albus*, *Neisseria flava*, and *Neisseria sicca*.

Roentgenographic examination of the mandible (Fig. 1-B) revealed a dense homogeneous thickening of the entire cortex. The unerupted teeth appeared normal. Roentgenograms of the skull, chest, and long bones were reported as negative.

The patient's hospital stay was relatively uneventful. The rectal temperature reached 100.4 degrees on the first hospital day and 100.2 degrees on the second day, but thereafter remained below 100 degrees. Following blood transfusions of 70 cubic centimeters and 120 cubic centimeters, the hemoglobin rose to 11.8 grams per 100 cubic centimeters and the red-blood-cell count to 4,100,000 per cubic millimeter. The blood sedimentation rate (Wintrobe method) was 28 millimeters on the seventeenth hospital day. The mandibular swelling remained unchanged, but no further swellings were noted. The patient was discharged on the nineteenth hospital day with the diagnosis of infantile cortical hyperostosis of the mandible.

On February 22, 1949, the baby was seen in the Out-Patient Department. Clinically, he was much improved. The mandibular swelling was decidedly decreased and the face was no longer tender. No other swellings had been observed by the mother. Roentgenographic study of the mandible revealed evidence of regressing cortical hyperostosis. There were accompanying segments of regressing hyperostosis in the femora and tibiae.

On March 2, 1950, clinical examination showed no evidence of infantile cortical hyperostosis. The child's mother reported that the mandibular swelling had disappeared about six months after onset. Roentgenograms of the mandible (Fig. 1-C) disclosed no osteal or periosteal abnormality. The cortex was regular and smooth; no changes suggestive of abnormality were noted.

FIG. 1-C

By March 2, 1950, the bilateral hyperostosis had disappeared.

FIG. 1-B

Roentgenogram of mandible, showing the cortical hyperostosis.

CASE 2. D. R., a first-born white male infant, two and one-half months old, was admitted to the Children's Ward of the Jewish Hospital on December 13, 1948. The present illness had begun eight days previously with the sudden onset of irritability, moderate anorexia, mucoid nasal discharge, and occasional nonproductive cough. On the same evening the father had noted tenderness and swelling over the right cheek and mandibular region. A local physician made the diagnosis of "upper-respiratory infection" and prescribed a sulfonamide preparation. During the next week, a low-grade fever, with rectal temperature ranging from 100 to 101 degrees, was noted, together with continued irritability and insomnia.

FIG. 2-A

FIG. 2-B

Fig. 2-A: D. R. Facial swelling can be seen on the right side.
Fig. 2-B: Roentgenogram of mandible, showing the cortical hyperostosis on the right side.

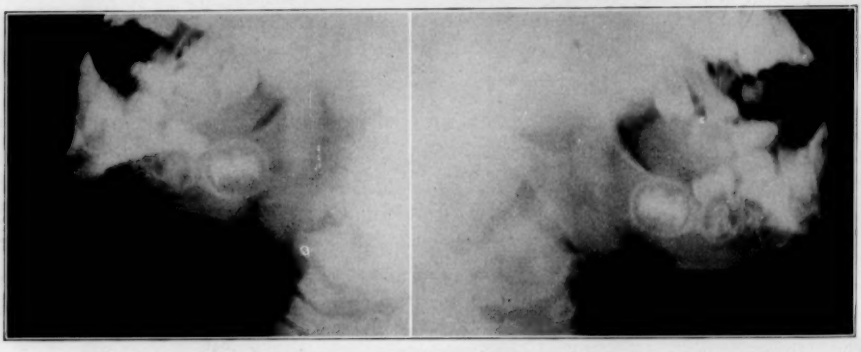

FIG. 2-C

In lateral roentgenograms (left and right views) taken on March 9, 1950, the mandible was considered normal.

At re-examination, five days after onset, the physician tentatively diagnosed the case as mumps.

The past history was negative except for pyloric stenosis at the age of one month, for which operation had been performed successfully at this Hospital. A postoperative wound infection healed after several weeks. There was no history of trauma or of a vitamin-deficient diet. The family history was non-contributory.

Physical examination at the time of admission revealed a well nourished white male infant with a swelling of the right cheek and submaxillary area; these regions were tender to palpation, but there was no fluctuation or redness (Fig. 2-A). The angle of the jaw was not obscured, and the right ear did not protrude. Mild injection of the pharyngeal mucosa was observed. The rectal temperature was 100.4 degrees. The child was irritable. The remainder of the physical examination was essentially negative.

Laboratory findings were as follows:

Red blood cells	3,830,000 per cubic millimeter
Hemoglobin	11.2 grams per 100 cubic centimeters
White blood cells	9,250 per cubic millimeter
Polymorphonuclear neutrophils	57 per cent. (82 per cent. filamentous)
Lymphocytes	39 per cent.
Monocytes	2 per cent.
Eosinophils	1 per cent.
Basophils	1 per cent.
Blood chemistry	
Calcium	10.0 milligrams per 100 cubic centimeters
Phosphorus	6.3 milligrams per 100 cubic centimeters
Alkaline phosphatase	4.8 Bodansky units

The urinalysis was negative. Examination of the tibial bone marrow was negative. Agglutination tests were negative for the development of antibodies against *Eberthella typhosa*, *Salmonella paratyphi*, *Salmonella schottmülleri*, Brucella, and Proteus OX19. Examination of the blood for heterophil antibodies and cold agglutinins was negative. The complement-fixation test for mumps antigen, performed at the Children's Hospital of Philadelphia, showed no evidence of infection with this virus. The Wassermann and Kahn tests were negative. There was no reaction following the intradermal injection of 0.1 cubic centimeter of purified protein derivative No. 1. A throat culture revealed hemolytic *Staphylococcus aureus*, *Streptococcus viridans*, and diphtheroids.

Roentgenographic examination revealed cortical hyperostosis of the ramus of the right mandible (Fig. 2-B). Roentgenograms of the chest showed a slight increase in the bronchovascular markings.

Clinically, the patient's hospital stay was uneventful. The rectal temperature reached 100.6 degrees for the first four days, then remained below 100 degrees until the day of discharge, when it again rose to 100.4 degrees. Daily intramuscular injections of 300,000 units of procaine-penicillin were begun on the fifth day, but gave no apparent benefit. A throat culture on the ninth day revealed non-hemolytic streptococci, *Staphylococcus albus*, *Neisseria flava*, and *Escherichia coli*.

The right mandibular area remained tender and swollen, but no other swellings appeared. The patient was discharged on the ninth day, unimproved. On February 22, 1949, when the patient was seen again, the mandibular swelling was gone. Physical examination at this time was entirely negative.

When the child was last examined, on March 9, 1950, no clinical evidence of the disease could be discerned. The mother reported that the mandibular swelling had disappeared about five months after onset. Roentgenographic examination of the mandible (Fig. 2-C) showed no evidence of osteal or periosteal abnormality.

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ANOMALIES OF THE CARPUS

With Particular Reference to the Bipartite Scaphoid (Navicular)

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Developmental variations of the human carpus are unusual. The most common is the bipartite navicular; less common are (1) the os centrale and (2) the fusion of two or more carpal bones. According to Todd and Cave, usually these anatomical variations are bilateral and there is no history of injury.

The bipartite carpal navicular is of special interest to the surgeon because the condition is often mistaken for an ununited fracture. This mistake is not at all surprising when one considers that (1) the line of division between the parts of a bipartite scaphoid is usually at the "waist" of the bone, which is frequently the site of an ununited fracture; (2) the examiner fails to consider variations of the carpus; and (3) a roentgenogram of the opposite wrist is often not obtained. Since these anomalies are frequently bilateral, the diagnosis is easily missed.

According to Todd, the statement that the carpal scaphoid in man might sometimes be bipartite was first made by Gruber in 1865. This opinion was based solely upon comparative anatomical studies. At a later date, Gruber was able to verify the statement. Codman and Chase stated that, from 1869 to 1883, Gruber saw 3,007 human scaphoids, of which four were bipartite and one was tripartite. Speed stated that, in 1900, Pfitzner reported the finding of nine complete bipartite scaphoids in the postmortem examination of 1,456 wrists. Codman and Chase, however, in 1,040 roentgenograms of wrists, did not find any divided scaphoid bones which were not definitely associated with injury. The authors have encountered bipartite scaphoids in two of approximately 1,400 roentgenograms of the wrist, taken in a period of a little over five years.

Cave and Wette wondered whether the occurrence of a bipartite carpal scaphoid was not always due to an old unrecognized fracture followed by pseudarthrosis, rather than to a true anomaly of the bone. Many authors [4, 6, 7, 11, 14], however, have reported the condition as a true anomaly.

Although Todd had never encountered a bipartite carpal scaphoid, he stated: ". . . one cannot deny that partition of the scaphoid does sometimes occur as a developmental reversion; but it is probable that many, and perhaps most, of the cases actually described have been ordinary cases of 'missed' fracture of the scaphoid". In cases of fracture, "the adjacent surfaces of the bones are always found to be rough, and to consist of cancellous bone; whereas, in true bipartite scaphoid, articular cartilage would always be found clothing them, and it would be perfectly smooth and glistening". Codman and Chase stated: "One can only accept the bipartite theory where the halves touch with smooth cartilaginous surfaces. In the cases in which we have operated this was not found to be the case." Nevertheless, Dwight cited Pfitzner as stating that, in a late stage, the adjacent surfaces of a bipartite carpal scaphoid may become roughened. In a case of suspected bipartite carpal scaphoid, based on roentgenographic findings, Faulkner excised the bone and concluded that it was a true bipartite scaphoid and definitely not a fracture.

Because of the rarity of bipartite carpal navicular and the fact that this condition, in two instances, was first mistaken for an ununited fracture, the report of these two cases seems warranted.

Case 1. J. F. C., aged twenty-three, a civilian electrician at the Naval Dry Dock, was first seen in the Out-Patient Clinic on January 11, 1943. On January 4, he had fallen, injuring his right wrist. There had been no previous injury to the right wrist, but he had had an injury to the left wrist three years previously.

FIG. 1-A

FIG. 1-B

Case 1. Roentgenograms of both wrists, showing bipartite scaphoid in each. (Reproduced, by permission, from *The American Journal of Surgery*, 67: 186, 1945.)

At that time he was treated in another hospital and had a plaster cast on his left wrist for about three weeks, following which he had made a full recovery.

The chief complaints were pain and tenderness of the right wrist. Examination revealed slight swelling and tenderness over the navicular and the dorsum of the wrist.

Roentgenograms of both wrists, taken on January 11 (Figs. 1-A and 1-B), were reported as follows: "Each carpal navicular bone is in two pieces. The line of division is smoothly and sharply outlined. It is wide and is bordered by well formed cortex. The line of the division presents a concavity facing proximally at the left wrist, and a very slight concavity at the right wrist. There is no evidence of degenerative or traumatic arthritis about the area of division, although each wrist shows evidence, particularly in the area of the capitate and multangular bones, of chronic arthritis with thinning of the cartilage, a tendency to ankylosis, and some fibrocystic degeneration. The arthritis is probably rheumatoid." The diagnoses were "contusion and sprain" of the right wrist, rheumatoid arthritis of both wrists, and an anomalous bipartite scaphoid, bilaterally.

A plaster cast was applied to the right wrist for six weeks, followed by a leather gauntlet and physical therapy. The patient returned to work eight weeks after the injury. He entered the Army in 1945. While in the Army he was in good health, having no trouble with either wrist until he suffered a "fall", receiving an injury to his left wrist. A plaster cast was applied to the wrist for six weeks, after which he returned to duty. He was discharged from the Army in 1946.

At a follow-up examination in September 1949, the patient stated that he continued to have a "little difficulty" with his left wrist—that is, discomfort and weakness after excessive use—but no trouble with the right wrist. Since his discharge he had been working for a telephone company and was getting along well. Check-up roentgenograms of both wrists showed: "There has been marked spread of arthritic changes in each wrist with extensive ankylosis now present, but the area of division of each navicular bone shows no arthritic change, either infectious or degenerative. The lines of division are somewhat narrower than in 1943, and this narrowing is believed due to conversion of some of the cartilage at the line of division into bone."

CASE 2. C. C., aged forty-five, a civilian shipfitter at the Naval Dry Dock, was examined in the Out-Patient Clinic on January 22, 1946. On that day, he had injured his left wrist, due to a fall on the outstretched hand. There was a history of a previous injury to both wrists at the age of fifteen, but he had received no treatment. He had had no trouble with either wrist up to the time of his present injury.

The patient complained of pain and weakness of the left wrist. There was slight swelling and redness over the dorsum.

Roentgenograms of both wrists, taken on the day of injury, were interpreted as follows (Fig. 2): "The left carpal navicular bone is in two pieces. The division is practically at the middle of the bone. The line of

division is smooth, even, wide, and is linked by well formed cortex. There is no reaction or traumatic arthritis about the lesion. A small fibrocystic area is present in the distal fragment, adjacent to the division. The contour of the division is somewhat angular, with the cavity of the angulation proximally. This is believed to be a congenital division. The styloid process of the ulna is demarcated from the bone by a thin cartilage line which is also believed to represent congenital division." The right wrist appeared normal.

The diagnoses were "contusion and sprain" of the left wrist, and an anomalous bipartite scaphoid.

Treatment consisted of physical therapy and an elastic bandage for compression and support of the wrist. The patient returned to work after a week. At a follow-up examination in September 1949, he stated that he had had no further trouble with his wrist and had been able to continue at work since his injury. Check-up roentgenograms showed no change from those taken in January 1946.

DEVELOPMENTAL CONSIDERATIONS

The development of the carpal bones usually follows a definite plan. At birth, the human carpus is entirely cartilaginous. Usually each carpal bone arises from one center of ossification [3,7,14]. More common exceptions are the navicular and the capitate, either of which may arise from two or even three centers [6,14,15].

According to Pfitzner, it is the development of a center of ossification of both the naviculare radiale and the naviculare ulnare that gives rise to the so-called bipartite scaphoid; and the additional center of ossification in the centrale gives rise to the rarer condition of tripartite carpal scaphoid. This explanation for the subdivision of the navicular, rather than failure of fusion of the embryonic os centrale with it [9] seems more credible for the following reasons: (1) The scaphoid is the one carpal bone most frequently arising from two or more elements; (2) the partition of carpal bones is more commonly limited to the scaphoid; and (3) the os centrale is a minute cartilaginous nodule and the disparity in size, shape, and position of the os centrale and the distal portion of a subdivided scaphoid would be too great.

Jones stated that the os centrale occurs normally in the mammalian carpus, including the embryonic human carpus, and in adult Primates, with the exception of the gorilla, the chimpanzee, and man.

FIG. 2

FIG. 3

Fig. 2: Case 2. Roentgenogram of left wrist, showing bipartite scaphoid. (Right wrist was normal.)
Fig. 3: Roentgenogram of right wrist, showing congenital fusion of the lunate and the triangular bones. (Left wrist was normal.)

Dwight stated that the os centrale "is one of the most uncommon bones to find distinct in the adult. For all practical purposes it is a dorsal element." The existence of the os centrale was prophesied by Dwight, long before any example of it had been found by the aid of roentgenograms in the hand of a living man. Dwight had based his assertions on studies in comparative anatomy and on examinations of the carpus in skeletons of prehistoric men.

In the literature, there is no agreement as to the fate of the embryonic os centrale. It has been variously reported (1) to disappear by a process of retrograde development; (2) "to degenerate and to be represented in the adult carpus as an inconsiderable ligament that passes between the os magnum and the scaphoid" [9]; and (3) to merge with the growing cartilages of neighboring bones,—that is, into the mass of the adult capitate or the adult navicular [9,14].

The most common of the fusion anomalies of the carpus (Fig. 3) is fusion of the lunate and the triangular bones [6,8,11]. In this connection Jones, referring to Gegenbaur's conception of the primitive carpus, stated: "The first modification of the ideal carpus is one that is evidently very early established in the phylogeny of the digitate vertebrates. . . ." This modification is fusion of the two distal carpal bones, articulating with the metacarpals of the fourth and fifth digits of the primitive carpus to form the hamate. "There is no mammal that does not show this numerical reduction of the carpalia" by fusion. Jones suggested, as the deep-seated factor to this development, the need for strength and stability on the postaxial border of the hand, demanded by the action of "pushing off" with downward and backward pressure, in contradistinction to the mobility required in the preaxial area for grasping. Jones also believed that the congenital fusion of the lunate and the triangular (Fig. 3) might indicate a further step in the stabilizing of the postaxial border of the hand.

Some of the less common fusion anomalies of the human carpus are the fusion of the capitate and hamate [6,11,17] and the fusion of all the carpal bones, sometimes associated with fusion of the contiguous carpophalangeal joints [2,6].

COMMENT

An adequate knowledge of both anatomical and developmental anomalies of the carpus is necessary for an accurate differential diagnosis between such anomalies and recent or ununited fractures of the scaphoid [1,10]. The division plane of a bipartite carpal scaphoid [6,15] is usually transverse or slightly oblique, and is situated in the middle portion or "waist" of the bone. The roentgenogram usually reveals a clear space between the portions of a divided scaphoid; the edges are smooth and regular and usually no arthritic changes are present [14]. However, according to Dwight and Pfitzner, it seems logical to expect some arthritic changes in the wrist joint (traumatic osteoporosis of the carpal bones [13]) to occur in certain individuals with a bipartite carpal navicular who in the past have subjected their wrists to undue stresses and strains,—that is, trauma short of fracture.

In the authors' first case, the divided carpal navicular, associated with rheumatoid arthritis and a history of injury, presents a picture that can be confused with an old ununited fracture (Preiser's disease). In such a case, it is evident that accurate diagnosis is dependent upon proper interpretation of the roentgenograms. A negative history of trauma and similar roentgenographic findings in the other wrist may be decisive factors in establishing a correct diagnosis.

NOTE: The authors are indebted to A. B. Ferguson, M.D., Boston, for his interpretation of the roentgenograms.

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PATELLA CUBITI

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Few cases of patella cubiti have been recorded. The most comprehensive review of the subject seems to be that by Habbe, who in 1942 reported four cases. He presented the historical analysis and roentgenographic findings, and tried to establish the etiology[3].

An English author, Gunn, had previously reported a case of patella cubiti in a woman, aged forty-six, with no previous history of elbow injury, who was knocked down by a bicycle. In roentgenograms, taken four days later, a fracture was found through the proximal end of the ulna, extending into the articular surface above the level of the fracture. A patella cubiti was also noted. In Gunn's case, the fracture healed by bony union after four months, but there was no change in the appearance of the cubital patella. His conclusions were that the latter was a persistence of a separation of the olecranon epiphysis.

The author had one case of an elbow patella, either bipartite or due to fracture, treated over eight years ago. Its significance was discussed with Eugene Freedman, Radiologist at the Cedars of Lebanon Hospital, who suggested that this case be reported.

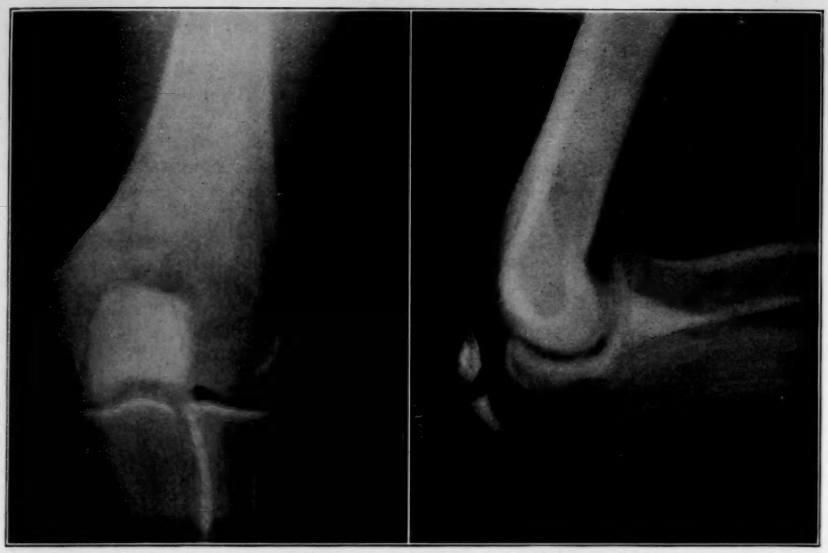

FIG. 1

S. S., a male Caucasian, aged fifteen years, was seen on July 22, 1941, complaining of pain and limitation of motion of the right elbow. The patient stated that, when playing football approximately three months before, he had been thrown while carrying the ball between his right arm and body. He struck his olecranon region while his elbow was acutely flexed. The pain was sudden and severe, but he continued to play and did not inform his parents of this mishap. Pain and stiffness became more severe after the third week, and he saw his family doctor, who later referred the patient.

Clinical examination showed a rather boggy right elbow, approximately 4.2 centimeters greater in circumference than that of the left side. Flexion was possible to 95 degrees, extension to 170 degrees. Pronation was complete; supination was limited to 30 degrees. Roentgenograms of the right elbow, taken on July 22, revealed a patella cubiti which was symmetrically spherical and was fractured transversely through its center. Its configuration was similar to that seen in the contact prints of Habbe's second case. The picture appeared more like a sesamoid developing in the triceps conjoined tendon, comparable with that of the patella genu, than an epiphyseal nucleus which had become separated prior to the accident (Fig. 1). No aberrant osseous shadows were noted in roentgenograms of the left elbow.

After consideration, a patellectomy was decided upon. The procedure was done with 1 per cent. novocain anaesthesia infiltration. The relationship of the aberrant patella cubiti to the elbow joint is homologous to that of the patella genu to the knee joint. A true synovial pouch was noted, in which the elbow-joint fluid was enclosed. The synovial lining of this pouch grossly had the appearance of the synovial pouch of the knee joint. Actually it looked like a miniature knee joint.

A microscopic examination was not made. Grossly, the patella had an articular cartilage which faced the ulna. After the patella had been excised, the triceps tendon was repaired. The lateral retinacular ligaments were approximated; the subcutaneous tissue and skin were closed. Ten days later, the patient had a moderately good range of motion; after six weeks, he had practically the same motion in the right elbow as in the left. Six months later, one could not ascertain any restriction of motion in either elbow.

COMMENT

This case seems to favor the theory that the aberrant patella arises in the tendon of the triceps humeri rather than from a previously separated epiphyseal nucleus.

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OCHRONOSIS

A Case Report * †

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A. S., a white male, aged thirty-five, was admitted to the Veterans Hospital on December 29, 1947, for the treatment of pain in the low back. In 1942, as he was carrying ammunition boxes while serving with the United States Army in New Guinea, he complained of aching pain in the low back, with radiation into the right leg. He was treated symptomatically with heat, massage, rest, and analgesics. His pain recurred at varying intervals of time, and was always aggravated by exertion. At the time of discharge from service in November 1945, he was awarded a partial-disability pension because of "arthritis of the spine".

Following return to civilian life, he was unable to perform his work as a mechanic because of persistent backache. He worked sporadically as a gasoline-station attendant. After wearing a back brace for eight months without relief of pain, he was admitted to the Hospital.

Physical examination showed a well developed and well nourished man. There was a full range of painless motion in the spine, but a slight loss of the lumbar lordosis. There was no muscle spasm in the back, but there was tenderness to percussion over the lumbar vertebrae and the lumbosacral joint. All leg signs were normal, and the reflexes were physiological. There were no motor or sensory changes.

Examination of the blood showed a hemoglobin determination of 14.5 grams, white-blood-cell count 11,650, and differential count normal. The blood Kahn test was negative. The fasting blood sugar was 93 milligrams per 100 cubic centimeters. The blood sedimentation rate varied between 1 and 16 millimeters per hour. Examination of the spinal fluid was negative. At the time of admission glycosuria of + + was reported in the urine, but subsequent analyses were negative. Agglutination tests for *Eberthella typhosa*, *Salmonella paratyphi*, *Salmonella schottmülleri*, and *Brucella melitensis* were negative. The intradermal tuberculin test was negative in serial dilutions.

Roentgenograms of the spine (Figs. 1-A and 1-B) revealed extensive narrowing of the intervertebral spaces in the lumbar area, with apparent displacement caused by the settling process and considerable loss of the normal lumbar lordosis. There was disintegration of the intervertebral discs. Lipping changes involved the margins of all the lumbar vertebral bodies. There were no remarkable changes in the thoracic or cervical spine, and roentgenograms of the ankles, knees, wrists, elbows, shoulders, and chest were normal.

Despite numerous consultations, a definite diagnosis could not be established. Treatment was unsatisfactory. Neither immobilization nor exercise was beneficial. Roentgenotherapy was of no value.

In another complete physical examination (by R.E.C.), a peculiar bluish-gray pigmentation, about one centimeter in diameter, was found in the antitragus on each side. A tentative diagnosis of ochronosis was then made. Further examination of the urine showed homogentisic acid in concentrations as high as 3.8 milligrams per 100 cubic centimeters. Specimens of urine gradually became very dark in color after exposure to the air, and the addition of alkali produced a similar effect immediately. Silver lactate (reagent of Folin and Wu) was reduced by urine without heat. A biopsy specimen from the right antitragus revealed "an irregular area of hyaline degeneration with ill defined areas of greenish-yellow discoloration of the cartilage. The cartilage cells in the pigmented area were pyknotic and small, and in the area of pigmentation the cartilage had been fragmented by the microtome". The diagnosis of alkaptonuric ochronosis was thus established.

At a postmortem examination in 1866, Virchow observed that the cartilages, tendons, ligaments, and intima of large vessels appeared to be blackened. When he further observed that the discoloration was due to pigment granules, which were ochre in color under the microscope, he suggested the term "ochronosis" for the condition. Seven years earlier, in 1859, Boedeker had discovered in the urine of a patient with glycosuria a second reducing substance which, because the urine turned black when alkalies were added, he called "*alcapton*". In 1891, Wolkow and Baumann isolated the substance and identified it as homogentisic acid. Garrod described alkaptonuria as an "inborn error of metabolism", and the pathogenesis has been traced to the incomplete oxidation of the amino

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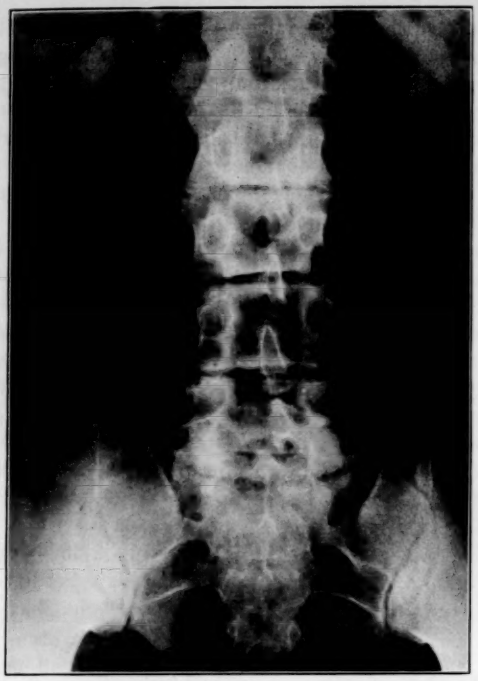

FIG. 1-A

FIG. 1-B

acids tyrosine and phenylalanine, with the formation of homogentisic acid as an intermediate product. Gross considered the error as a deficiency of a specific enzyme. The homogentisic acid is not only excreted in the urine as a foreign substance, but is also distributed throughout the body as an ochronotic pigment which has an affinity for certain tissues, and thus gives rise to the characteristic clinical picture. Falta demonstrated that the amount of homogentisic acid excreted in the urine varied directly with the amount of phenylalanine and tyrosine ingested as proteins in the diet. However, Mittelbach showed that, although the quantity of excretion of the acid was decreased by abstinence from protein, it was not eliminated completely; he concluded that catabolism of body protein contributed to formation of the acid.

Oppenheimer and Kline classified ochronosis etiologically as associated with excretion of (1) homogentisic acid or (2) melanin. Melanuria is rarer, but for clarity the term "alkaptonuric ochronosis" is used frequently in the literature. Although ochronosis may occur in an exogenous form, as a result of the excessive use of phenol and its derivatives, such cases are uncommon.

In most cases, the disease has a familial tendency, and it is inherited as a recessive Mendelian characteristic in the offspring of consanguineous parents. The first sign of alkaptonuria is usually noted in infancy; the urine becomes a brownish-black color after exposure to air and stains the diapers. Later, as ochronosis develops, the patient presents a fairly typical clinical picture.

Howard and Mills described the diagnostic signs as (1) pigmentation of the ears and sclera, (2) dark color of the urine, and (3) arthritis deformans. The ochronotic pigment is deposited principally in the articular cartilages, especially in older cartilages with poor metabolic exchange. The cartilage darkens, becomes brittle, and has little resistance to mechanical strain. Larger joints are involved earlier and more often than smaller joints. The pigment is also deposited in fibrocartilages, such as the annulus of an inter-

vertebral disc, pelvic cartilage, and costal cartilage. In addition to the skeletal deposits, the pigment is found in the endocardium, intima of large vessels, kidneys, tonsils, lungs, thyroid, and some fatty tissues. Pigment is almost always found in the sclera and epidermis. There is often yellowish or brownish mottled skin on the head, neck, and torso. Garrod described a butterfly-shaped brownish facial pigmentation. Others found early evidence demonstrated by a grayish-blue discoloration of the ear cartilages, first seen in the concha and the anthelix, and later in the tragus. The ears may become nodular and rigid to palpation. The nose may also acquire a bluish tint.

Kyphosis of the thoracic spine may develop, but in the lumbar region there may be either exaggeration or obliteration of the normal lordosis [9]. As in most of the non-specific arthritides, the vertebral bodies usually maintain normal height, but generalized osteoporosis affects all of the spinal segments. Ankylosis of the vertebral bodies and joints results in rigidity of the spine. When the cartilage of the intervertebral disc becomes infiltrated with the pigment of homogentisic acid, a degenerative process follows with calcification of the disc. A striking roentgen picture is thus produced, characterized by narrowing of the intervertebral-disc space, anterior or posterior subluxation of the vertebral bodies, and dense calcification of the remaining disc. Deforming osteo-arthritis of the spine, first described by Osler in 1904 in his report on ochronosis, is frequently the complaint for which the patient consults his physician.

No specific therapy has been established for this disease. Although it is slowly progressive, it apparently has little effect on longevity. In the case presented, a diet low in tyrosine and phenylalanine has been tried, but the subjective benefit is questionable.

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POST-TRAUMATIC ASEPTIC NECROSIS OF THE DISTAL TIBIAL EPIPHYSIS

Report of a Case *

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There are at least two main types of injury to the growing epiphyses of the long bones which may be productive of deforming and painful sequelae. One group consists of injuries to the growth zone, severe enough to produce complete or eccentric arrest of growth. This has been observed in most epiphyses, and has been studied comprehensively. The second, and less common, type of epiphyseal injury compromises the major, critical blood supply to the epiphyseal segment, producing massive necrosis. It has been observed most frequently at the proximal femoral capital epiphysis.

In the case reported here, aseptic necrosis of the distal tibial epiphysis resulted from a crush injury. No previous reports of post-traumatic aseptic necrosis involving this area have been found.

J. S., an eleven-year-old white boy, was brought to Mount Sinai Hospital on July 31, 1945, having been struck by an automobile and rendered unconscious. At the time of admission the patient was in mild shock, but was fairly well oriented. There was marked deformity of the right ankle and tenderness over the skull. A Babinski reflex was present on the left and supported the impression of cerebral concussion. Roentgenograms revealed a six-inch linear fracture of the right parietal bone and fractures of the posterior portions of the eleventh and twelfth ribs. Examination of the right ankle revealed a comminuted fracture of the lower aspect of the shaft of the fibula, a transverse fracture through the base of the medial malleolus, and a crush injury of the lateral half of the distal tibial epiphysis (Fig. 1).

Fig. 1

Anteroposterior and lateral roentgenograms demonstrating bimalleolar fracture of the ankle and crush injury of the lateral half of the distal tibial epiphysis.

Because of the patient's poor general condition, a reduction was attempted without anaesthesia; this was unsatisfactory. On the following day, reduction was repeated under local anaesthesia. Roentgenograms demonstrated very little improvement in the position. On the fifth day the boy's general condition had improved, and reduction was again attempted under roentgenographic control and general anaesthesia. Post-reduction roentgenograms showed marked improvement in position (Fig. 2). Full reduction seemed to be impossible because of obliquity of the lower articular surface of the tibia, due to the crushing of the lateral

* Read before the New York Academy of Medicine, April 18, 1947.

** Robert K. Lippmann, M.D., Director.

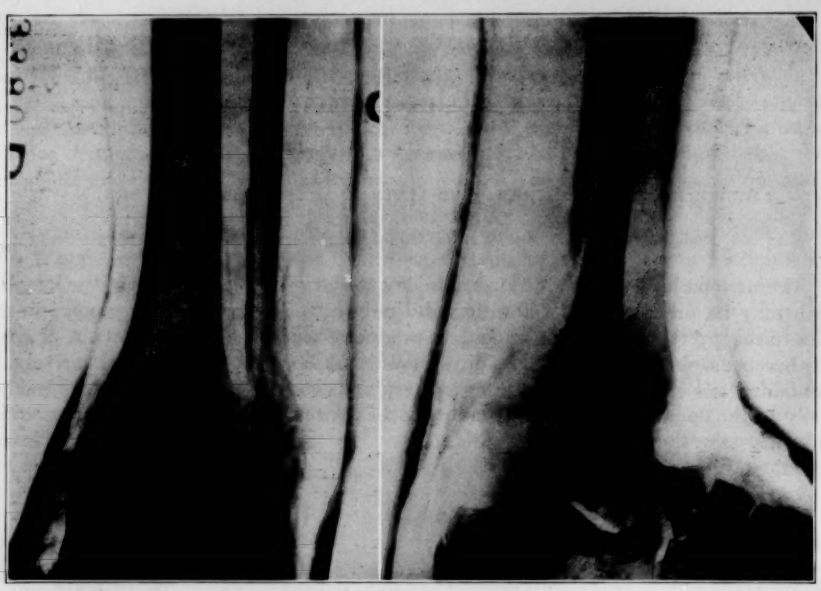

FIG. 2

Anteroposterior and lateral roentgenograms demonstrating the postreduction position.

FIG. 3

Anteroposterior and lateral roentgenograms, thirteen months after injury, show the irregular, dense, sclerotic, and fragmented distal tibial epiphysis with non-union of the medial malleolus.

FIG. 4

Lateral roentgenogram taken three years after operation shows firm fusion and complete replacement of the necrotic bone.

FIG. 5

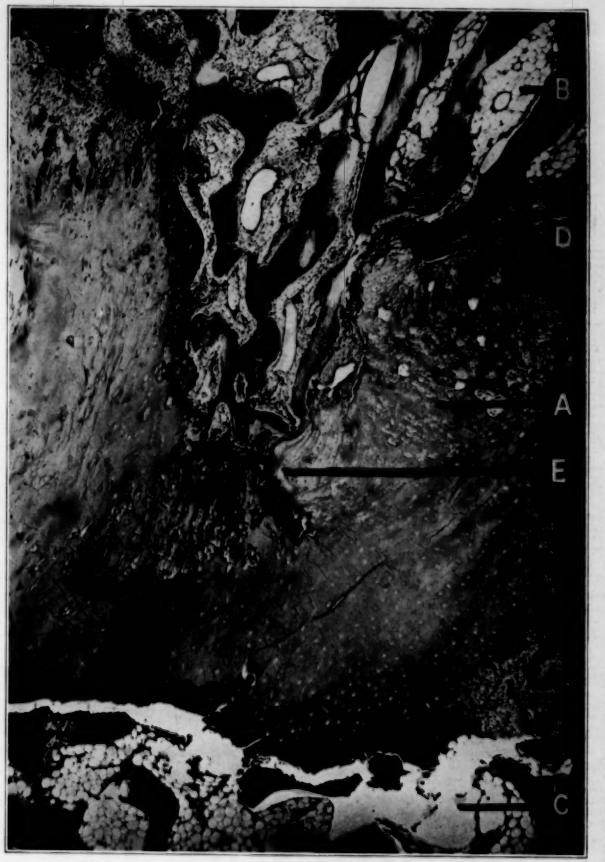

FIG. 6

Fig. 5: Low-power photomicrograph of curettings from the center of the distal tibial epiphysis (Specimen 1). Aseptic necrosis is represented by empty lacunar spaces and complete degeneration of the marrow.

Fig. 6: Specimen 2. Low-power photomicrograph of the anterior portion of the epiphyseal cartilage (*A*) with the adjacent portion of metaphysis (*B*) and epiphysis (*C*). Note replacement of the growth zone by bone trabeculae parallel to the surface of the cartilage; fibrous tissue (*D*) intervenes. Leading the penetration of the epiphyseal cartilage by metaphyseal bone trabeculae is a bed of granulation tissue (*E*), containing numerous giant cells.

aspect of the epiphysis. The cast was changed in two weeks with no loss of position, and the patient was discharged on the eighteenth hospital day. He walked on crutches; weight-bearing was not permitted. The cast was removed two months after injury, and the patient began gradual weight-bearing. Roentgenograms at that time showed non-union of the medial malleolus, good union of the fibula, and slight widening of the ankle mortise. The lower tibial articular surface was not horizontal.

Shortly after removal of the plaster, the patient complained of gradually increasing pain, swelling, and disability of the ankle, which steadily and severely limited his activity. The pain was most pronounced after he stood or walked for any period of time, or when he attempted to run. Examination thirteen months after injury disclosed severe pain at the extremes of motion; motion was limited to about 60 per cent. of normal. There was marked generalized tenderness and swelling over the entire ankle, but no increase in local warmth. All motion produced marked crepitus. The patient walked with a moderate limp. Measurement of both tibiae on the roentgenogram disclosed that the affected bone was one-quarter of an inch shorter than the opposite tibia. There was non-union of the medial malleolus. The epiphysis was densely sclerosed, irregular, compressed, and fragmented. There was also slight sclerosis of the adjacent metaphysis, and the mortise was slightly tilted. A clinical diagnosis of aseptic necrosis was made (Fig. 3).

On September 14, 1946, fourteen months after the original injury, ankle fusion was performed. The cartilage of the articular surface of the tibia was fragmented and friable. The cartilage of the talus was normal. The subchondral bone of the distal tibial epiphysis was gritty, spongy, friable, and fragmented easily on curettage. A section of this tissue was removed from the center of the epiphysis (Specimen 1). Epiphyseodesis of the fibula was performed by excision of the distal epiphyseal cartilage plate. After all articular cartilage had been denuded thoroughly, an anterior sliding bone graft from the lower end of the tibia was inserted across the ankle joint into a channel in the talus. The lower 1.7 centimeters of the graft, which represented epiphysis, epiphyseal line, and a small portion of the metaphysis, was retained (Specimen 2). The remainder of the graft was wedged into the bed. Postoperative fixation was excellent; the course was uneventful; and the patient was allowed to bear weight in a boot cast and a walking iron one month after operation. His course was followed by means of serial roentgenograms.

At the end of five months there was evidence of clinical union; two months later the roentgenograms showed solid fusion. The boy was followed for over three years after operation and continued to be free from symptoms. At that time, roentgenograms revealed firm arthrodesis with full replacement of the necrotic bone (Fig. 4). The right lower extremity was one and one-quarter inches shorter than the left; the right tibia, as measured by roentgenograms, was one inch shortened. In spite of the ankle fusion, function was excellent, due to an increase in the range of motion through the mid-tarsal and subtalar joints.

Histological examination of the specimens gave the following findings:

Specimen 1 (Fig. 5), representing curettings from the center of the distal tibial epiphysis, demonstrated true aseptic necrosis. The lacunar spaces were devoid of osteoblasts and there was no evidence of viable cellular elements in the section. The marrow was completely degenerated, with no signs of revascularization, or of osteoblastic or osteoclastic activity. The specimen was prepared by routine decalcification and embedding in paraffin.

Specimen 2 represented the lower 1.7 centimeters of sliding bone graft; it measured 1.0 centimeter in depth. The epiphyseal line, the adjacent epiphysis, and the metaphysis were thoroughly studied. The posterior half of the section demonstrated normal epiphyseal cartilage with growth columns. The anterior half (Fig. 6) revealed a much widened epiphyseal cartilage with no evidence of active growth. In the place of the growth columns on the metaphyseal side of the cartilage were dense trabeculae, parallel to the surface of the cartilage. Between the cartilage and the bone trabeculae was a thin sheet of dense fibrous tissue. In the center of the section several bone trabeculae, surrounded by osteoblasts, penetrated deeply into the epiphyseal cartilage from the metaphysis. Leading the invasion was a pocket of granulation tissue, containing blood vessels and numerous small giant cells. It was felt that this area represented a phase of the invasion of the non-growing epiphyseal cartilage, which would eventually result in complete premature union and obliteration of the epiphyseal cartilage. The metaphysis and epiphysis of Specimen 2 showed extensive marrow fibrosis. There was no evidence of aseptic necrosis, or of osteoblastic or osteoclastic activity. This specimen was prepared for study by the celloidin-embedding method.

BILATERAL STRESS FRACTURE OF THE NECK OF THE FEMUR

Report of a Case

BY LEO FREDERICK MILLER, M.D., CHICAGO, ILLINOIS

From the Section on Orthopaedics, Mount Sinai Hospital, and the Department of Orthopaedics, University of Illinois College of Medicine, Chicago

Although stress, fatigue, spontaneous, or marching fracture has been reported in all bones of the lower extremities and in the pelvis, ribs, humerus, and vertebrae, no record has been found of its simultaneous occurrence in the necks of both femora. Hartley, in 1943, stated that, although the condition may be bilateral, he had never observed either the onset of symptoms or the roentgenographic picture simultaneously in both limbs. Proctor, Campbell, and Dobelle, Hartley [1], and others have reported bilateral fracture in other bones, notably the tibiae. Stress fracture following roentgenotherapy also has been reported.

In the following case, stress fracture of the neck of the femur was bilateral:

P. N., a white stenographer, aged thirty-six, was examined on March 23, 1946. She complained of pain in the lower part of the back and in both hips, which radiated to the groin and down the medial and posterior aspects of both lower extremities as far as the ankles. She had felt perfectly well until two months before, when pain had developed suddenly in the back, with occasional radiation down both lower extremities. This was worse on the right side. The pain was constant and aching, with intermittent cramping. Bed rest gave relief, but the symptoms would recur when she arose. There was a feeling of instability in both lower extremities.

The patient had had frequent attacks of diarrhoea for several years, and several physicians had attributed these to non-specific colitis. Her menses had always been irregular. A cyst had been removed from her left breast in 1942.

On physical examination the patient walked with the hips flexed, the pelvis tilted backward, and both lower extremities held in adduction. Attempts at abduction of the hips produced pain in the inguinal region on each side. The adductor muscles were in spasm. Tenderness was present over the lumbosacral joint and in the inguinal region. There was no atrophy of the legs or disparity in length. Knee and ankle reflexes were normal, and there was no sensory loss.

Examination of the blood was as follows:

Red blood cells	3,720,000
Hemoglobin	10.2 grams (61.2 per cent.)
Color index	0.82
White blood cells	5,400
Polymorphonuclear neutrophils	59 per cent.
Monocytes	3 per cent.
Small lymphocytes	32 per cent.
Eosinophils	3 per cent.
Stab cells	3 per cent.

The sedimentation rate (Wintrobe method) was 21 millimeters per hour. A smear of blood showed slight microcytosis and hypochromia, moderate anisocytosis and poikilocytosis, and occasional target cells. Chemical study showed, per 100 cubic centimeters, 92 milligrams of sugar, 3.7 milligrams of phosphorus, and 9.8 milligrams of urea nitrogen; the phosphatase was 16.5 units.

No free acid was present in the gastric washings. The urine showed no abnormality. There was no Bence-Jones protein. The basal metabolic rate was +6 per cent.

The patient was admitted to the Hospital on March 24, and absolute bed rest was ordered. She was given a high-caloric diet, a multiple-vitamin preparation, and 10 minims of dilute hydrochloric acid three times daily. On March 25, a lateral roentgenogram of the lumbosacral portion of the spine showed acute angulation of the sacrum, beyond the degree considered favorable for weight-bearing. Anteroposterior roentgenograms of both hips (Fig. 1) showed an area of dehiscence extending through the inner aspect of each femoral neck at approximately the point exposed to most stress. The fracture line was widest at its innermost point and gradually faded. The patient's pain subsided gradually.

On April 11, in roentgenograms taken of both hip joints at close range, the fracture lines were less clear than before, indicating slight healing. On April 22, the fracture lines were still visible (Fig. 2), but were not so clear as they had been earlier. By April 25 the pain was entirely gone, and the patient was discharged from the Hospital with instructions to remain in bed or in a wheelchair at home.

On May 26 she experienced a recurrence of mild, vague pain in both lower extremities, without tenderness or spasm. Hubbard-tank baths and general massage gave immediate relief, and she was allowed to bear weight with crutches. She discarded the crutches on June 29, when roentgenograms (Figs. 3-A and 3-B) showed almost complete disappearance of the fracture lines in the femoral necks and solid bony union without deformity.

On November 27, when last seen, the patient was free from all symptoms and had returned to work. Anteroposterior and lateral roentgenograms of both hips showed complete healing of the stress fractures

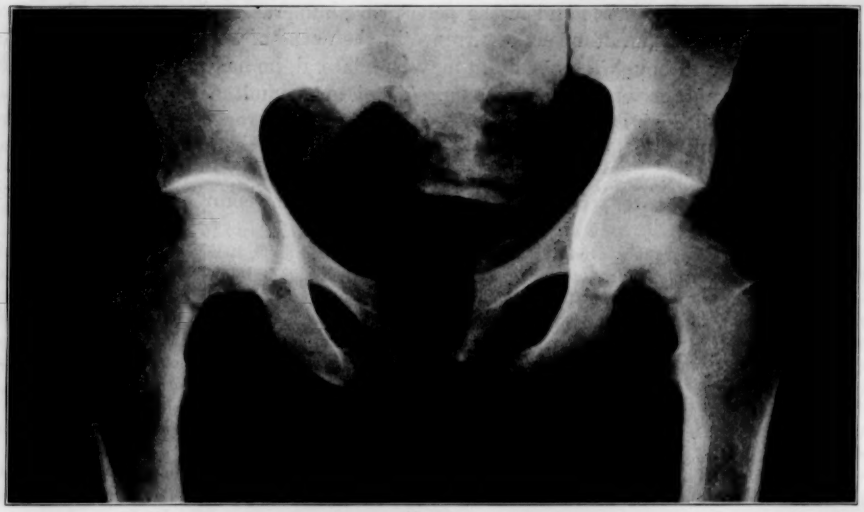

FIG. 1

Roentgenogram of the lumbosacral region of the spine (March 25, 1946), showing fracture line through the inner aspect of the necks of both femora.

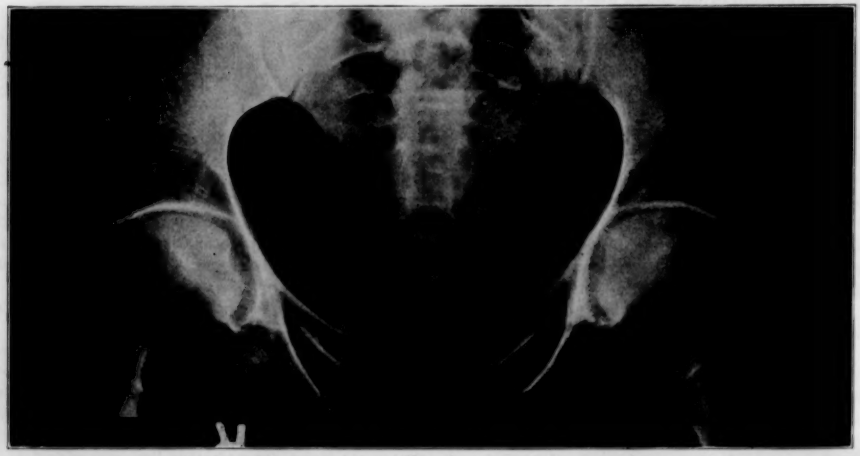

FIG. 2

In roentgenogram of April 22, fracture lines are still visible, but appear to be healing.

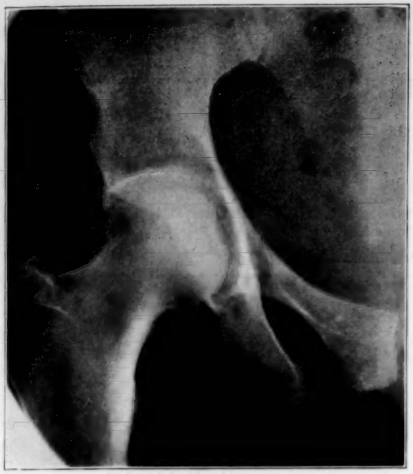

FIG. 3-A

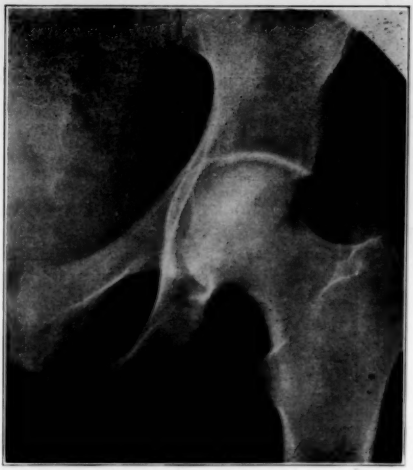

FIG. 3-B

Roentgenograms of right and left pelvic regions, taken on June 29. The fracture lines had almost completely disappeared, and there was solid bony union without deformity.

of the necks of both femora. The fracture lines could not be made out, and the bony architecture of the necks of the femora appeared normal.

COMMENT

The symmetrical appearance of the fracture lines on roentgenographic examination and the absence of injury suggested fatigue fracture. The acute angle of the sacrum, however, may have been an important contributory factor. Scott stated that mild hypothyroidism may be a predisposing systemic cause, and that mild osteoporosis may develop with this condition, as with hyperpituitary and menopausal syndromes. The menstrual disturbances in this case may have been part of such a syndrome.

The absence of free hydrochloric acid in gastric washings and the repeated attacks of diarrhoea suggest a chemical disturbance of the blood, but no evidence of this was elicited.

Stress fractures usually are seen in sedentary persons who have suddenly been thrown into strenuous activity,—for example, in those suddenly transferred from civilian to military life. This patient, however, had never engaged in strenuous activity.

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3. PROCTOR, S. E.; CAMPBELL, T. A.; and DOBELLE, MARTIN: March Fractures of Tibia and Femur. Surg., Gynec., and Obstet., **78**: 415–418, 1944.
4. SCOTT, WALTER: March Fractures. Surg., Gynec., and Obstet., **81**: 525–529, 1945.

BUTTONHOOK RETRACTOR FOR HAND SURGERY

BY JULIAN M. BRUNER, M.D., DES MOINES, IOWA

A useful instrument for surgery of the hand is a blunt hook, modeled after the old-fashioned buttonhook, which is made of stainless steel and provided with a suitable handle (Fig. 1).

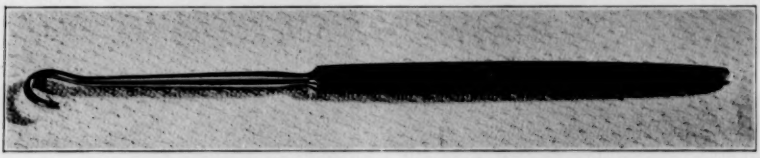

FIG. I

In tendon surgery it is often necessary to isolate and extract individual flexor tendons of the sublimis or profundus group for suture, transfer, or grafting. The buttonhook, being smooth and causing relatively little trauma, performs this function better than any other instrument, either in the finger, the palm, or the wrist.

In surgical dissections in the hand, such as those necessary in the removal of the palmar aponeurosis for the relief of Dupuytren's contracture, the buttonhook serves as a perfect retractor. The lumbricalis structures can be pulled aside, thereby facilitating removal of the arcades of the palmar fascia without danger of injury to digital nerves and vessels.

The buttonhook, therefore, serves a dual purpose as tendon extractor or retractor.

NOTE: No credit is claimed by the author for originality in the use of this instrument. An ordinary buttonhook has been used previously by others for surgery of the hand, but a proper instrument of rustless steel has not been readily available heretofore.

THE PUNCHING BAG IN REHABILITATION*

BY J. L. RUDD, M.D., AND REUBEN J. MARGOLIN, M.A., BOSTON, MASSACHUSETTS

From the Physical Medicine Rehabilitation Service and the Department of Corrective Therapy, Veterans Administration Hospital, West Roxbury

A valuable piece of exercise equipment for a medical gymnasium—potentially useful, but seldom employed—is the punching bag. It is readily available; the overhead platform drum is easily constructed; and it is inexpensive.

In any exercise program, one of the first factors to be considered is avoidance of the monotony and boredom of the routine prescription. A second factor is the improvement of a specific pathological condition as a result of the activity.

Carefully selected cases of shoulder disability have been treated by the use of the inflated pear-shaped leather bag, in addition to the usual physical, occupational, and cor-

* Published with approval of the Deans' Committee, Department of Medicine and Surgery, Veterans Administration, who assume no responsibility for the opinions expressed or the conclusions drawn by the authors.

rective therapy. A number of diseases and injuries of the upper extremities, especially in the region of the shoulder and elbow, are amenable to this type of corrective therapy. Patients with subdeltoid or subacromial bursitis, as well as those with dislocation or fracture of the shoulder or elbow joint, can expect gains in strength and in range of motion in specific planes.

In certain conditions, we were able to aid the patient in regaining an appreciable measure of coordination and rhythm. Few gymnasium exercises require a greater synergistic action of muscles than striking the bag. Rhythmic mental responses foster the element of awareness, aid in re-establishing the reflex arc, and combat what may be a very disabling psychological block or "mental alienation".

All punching-bag exercises should progress from the very simple to the more complex. The patient should learn to strike the bag in a manner which will benefit his particular condition.

1. *Straight Punching Exercise:* This is a direct forward movement in the horizontal plane, straight from the shoulder. In striking the bag, regardless of the exercise, the principle is the same,—that is, one should first strike the bag just below its center and then wait for it to carom off the drum or overhead platform, the hand being kept in a position preparatory to striking the bag as it returns to a central point beneath the platform. This simple activity involves a synergistic action of the whole upper extremity.

2. *Hooking the Bag:* This exercise is performed in a lateral plane, the subject bringing the forearm across the chest with elbows flexed at 90 degrees.

3. *Combination Straight and Side Punching:* This movement is started in the horizontal plane as in the straight punching exercise, and is completed by extending the forearm (flexed at 90 degrees) and striking the bag in the oblique plane.

4. *Rotary Tattoo Punching:* From a position midway between pronation and supination, the wrists and hands revolve over each other with the elbows flexed at 90 degrees, while the subject strikes the bag.

These are a few of the simpler methods of striking the bag, but additional complicated movements have been improvised.

After the acute stage of bursitis has passed, when increased motion in abduction and forward flexion is sought, a low-hanging punching bag may be employed, in addition to the usual physical therapy. As strength returns to the muscles around the shoulder girdle and as the range of motion increases, the bag is raised and the force and rapidity of the blows are progressively increased. Absorption in this activity minimizes the feeling of pain and allows greater joint mobility. This interest has been found more difficult to evoke in other routine shoulder exercises.

For recurrent dislocation, straight punching exercises can be used to build up muscle tone and to enlarge and strengthen the muscle mass around the shoulder girdle. In this way the head of the humerus can be given more muscle support, to help keep it in the glenoid fossa in spite of a stretched and torn capsule. Straight punching avoids abduction and external rotation, the motions most likely to cause recurrence of the shoulder dislocation. If all efforts to prevent recurrent dislocation fail and an operation by the Bankart method is necessary, punching-bag exercises can be started as soon as the orthopaedic surgeon assigns the patient for physical therapy, repeated precautions being given regarding the motions of abduction and external rotation.

For fractures about the elbow joint, a punching motion with pulley weights affords effective rehabilitation. However, active extension of the elbow against resistance, with reflex relaxation of the flexors, can be most effectively accomplished by straight punching of the bag. Again, the absorption in the "doing" and the "learning" of the skill lessens concentration on pain, thus allowing more activity earlier. The progressive nature of supervised learning ensures protection against overexertion.

The shoulder-hand syndrome, the nature of which is not completely understood,

consists of pain in the shoulder or hand, or both. Shoulder motion is limited by pain; the affected hand becomes oedematous and so uncomfortable that it is held stiffly. One of the best methods of treating such a causalgic state is believed to be vigorous therapeutic exercise, which should be continued for a long period, despite the attendant discomfort and pain. The punching bag can be beneficially employed in the few patients with the shoulder-hand syndrome who are able to concentrate sufficiently on this activity to lessen their attention on the pain caused by the motion of the upper extremity.

A SELF-RETAINING RETRACTOR FOR OPERATIONS ON LONG BONES

BY HERBERT E. HIPPS, M D., WACO, TEXAS

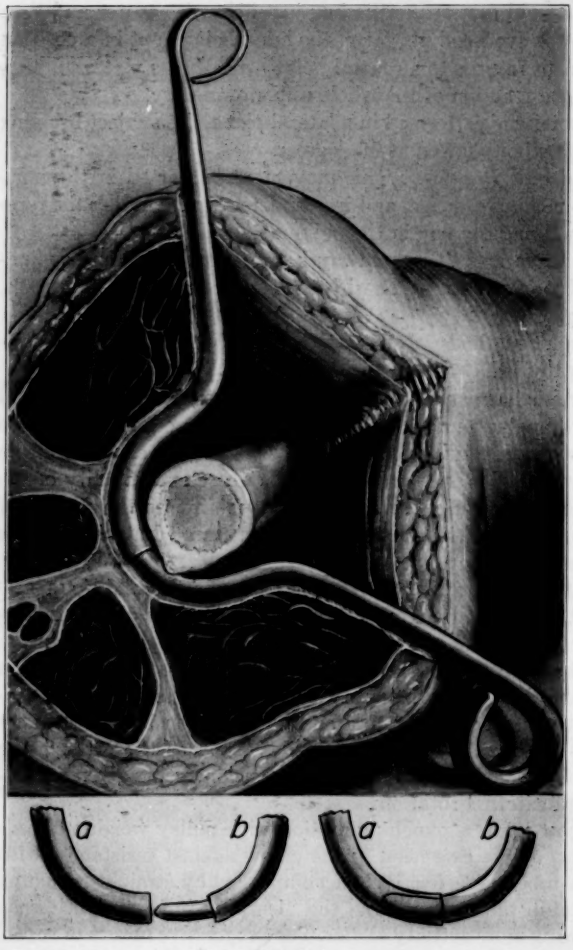

FIG. 1

The retractor which is described here satisfactorily and constantly exposes more than one-half of the circumference of a long bone in the field of operation. It offers the advantage that it does not need to be held in place. It is easy to apply, needs no adjusting, and can be made by almost any bracemaker or machinist.

The instrument is made of two pieces of strong metal tubing of small diameter, shaped as shown in Figure 1. One piece is longer than the other. Into the end of the longer piece is brazed a short, solid rod, which is slightly pointed on one end (Fig. 1, inset).

In using the retractor, the longer portion is applied first. It should be inserted between the bone and the soft tissue, the muscle being pushed back by leverage action. This brings the pointed end into view on the opposite side of the bone. The open end of the second piece (*a*) is then pushed over the pointed end, thus locking the retractor in place.

UNIVERSAL STAPLER

BY WILLIAM H. VON LACKUM, M.D., NEW YORK, N. Y.

The increasing frequency with which staples of various sizes are employed in surgical bone procedures has led to an effort to devise an instrument that will grasp the staples securely and aid in easier and simpler insertion, particularly in deep wounds.

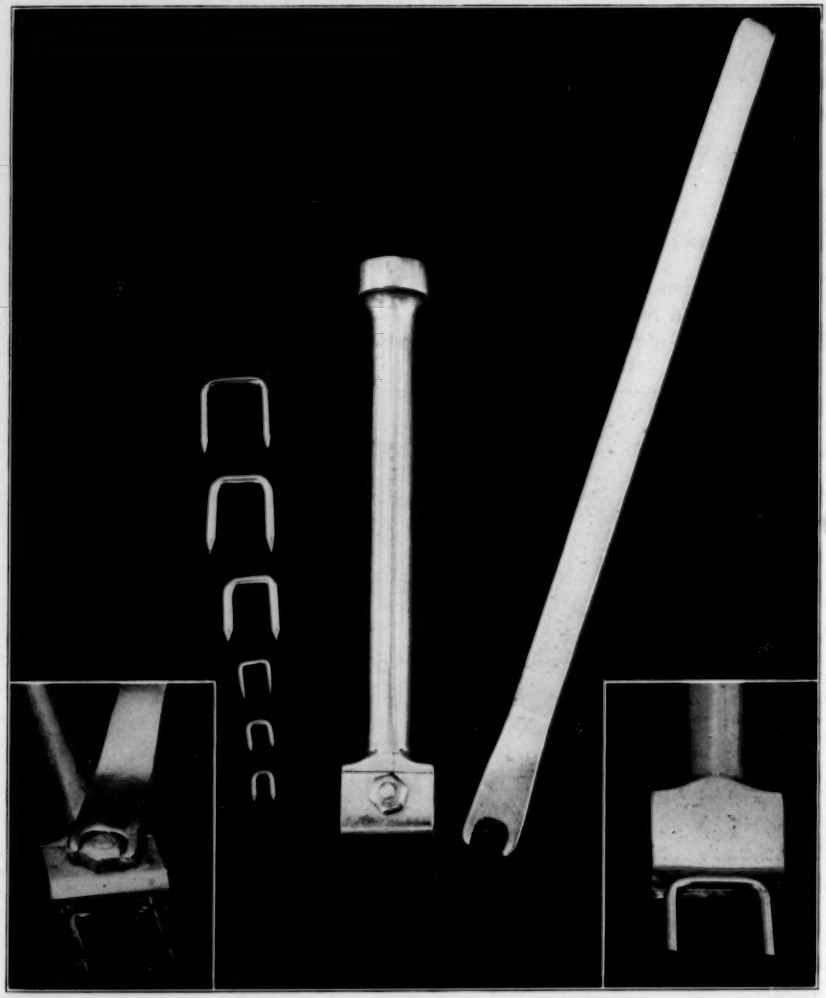

FIG. 1

Figure 1 shows the combination of grasping tool and wrench, together with a wide selection of staples of varied sizes, each of which can be driven with equal advantage.

A staple of any size is grasped in the jaws of the impacting tool and fixed there by applying the wrench to the hexagonal nut. The staple is then ready to be driven into any exposed site, whether deep or superficial. After the staple has been inserted a portion

of its full depth, the nut is released, thus disengaging the impactor from the staple. If the groove, noted in the end of the impactor, is then butted against the transverse bar of the staple, the latter can be quickly and easily driven to its secure full depth.

The instrument has the particular advantage of being capable of reaching a wound of any depth and of being accurate, quick, and positive in its insertions.

A TABLE EXTENSION TO AID IN APPLICATION OF SHOULDER SPICA

BY H. KELVIN MAGILL, M.D., BOSTON, MASSACHUSETTS

From the Bone and Joint Service, Out-Patient Department, Boston City Hospital

The application of a shoulder spica to a patient who is supine or sleeping requires the utilization of a removable back support of some type. Numerous modifications of this principle were, of necessity, utilized in World War II.

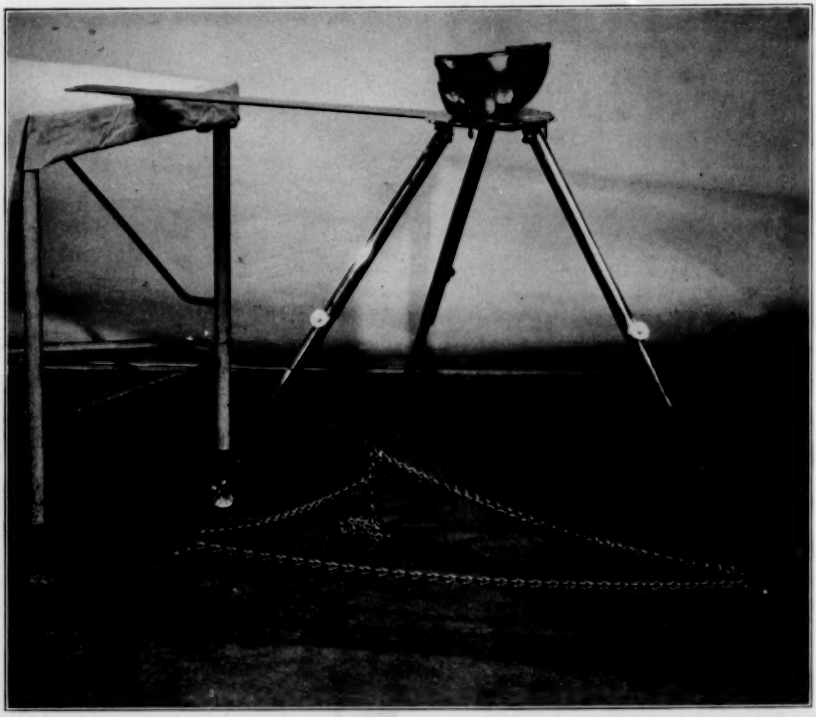

FIG. 1

Tripod table extension, showing legs extended, with chain in position to prevent legs from spreading. Back support is parallel to top of table.

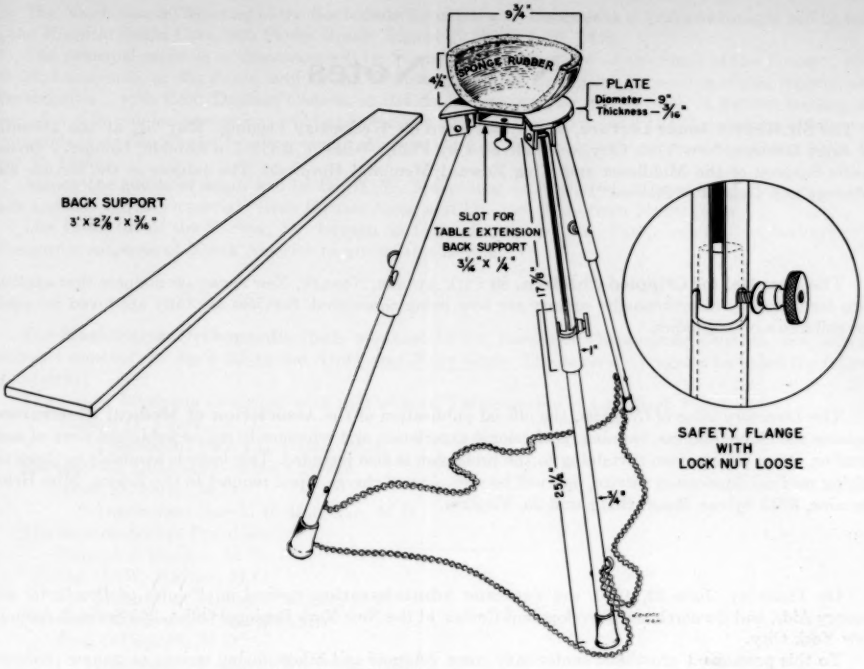

FIG. 2

Dimensions and specifications of apparatus. Inset shows details of safety flange, used to prevent collapse of legs of tripod.

The apparatus described here employs this old principle by means of a chrome-plated metal, removable back support, attached just beneath the head support, which is mounted upon an adjustable tripod. The head piece is a sectioned stainless-steel salad bowl, with a sponge-rubber insert. The legs of the tripod are chrome-plated pipe, attached to the metal disc with hinges, so that the tripod can be adjusted to a table of any feasible height. The legs also present two other features of practical value: (1) A lock flange prevents their collapse when extended to full length, even when the lock nut is not tight; (2) telescoping of the legs facilitates easy transportation of the apparatus.

This tripod table extension has proved a useful adjunct in procuring better reductions of fractures of the clavicle, permitting easy application of figure-of-eight bandages or plaster-of-Paris splints, plaster vests, or spicas, as required in treatment of certain injuries of the upper extremity.

OMISSION

In the article entitled "Early Effects of Partial Sensory Denervation of the Hip for Relief of Pain in Chronic Arthritis" by Benjamin E. Obletz, M.D., and associates, published in a recent issue of *The Journal* (Vol. 31-A, No. 4, pages 805–814, October 1949), no mention was made of Dr. Ober's technique for drainage of the hip joint. Dr. Obletz regrets that he failed to realize the similarity between the method described in this article and the surgical approach previously described by Dr. Ober. Dr. Ober's article entitled "Posterior Arthrotomy of the Hip Joint. Report of Five Cases" appeared in the *Journal of the American Medical Association* for November 8, 1924 (Vol. 83, pages 1500–1502).

News Notes

The **Sir Robert Jones Lecture,** which was given on Wednesday evening, May 31, at the Hospital for Joint Diseases, New York City, was delivered by Philip Wiles, F.R.C.S., of London, Honorary Orthopaedic Surgeon of the Middlesex and King Edward Memorial Hospitals. The subject of the lecture was "Posture and Defects of Posture".

The Hospital for Crippled Children, 89 Park Avenue, Newark, New Jersey, announces that applications for residency in orthopaedic surgery are now being considered. Services are fully approved for adult and children's orthopaedics.

The Directory issue of *Graphics*, the official publication of the **Association of Medical Illustrators,** contains the name, address, training, professional experience, and reference to major published work of each member. Other information pertaining to the profession is also included. This issue is available to those requiring medical illustration service, and will be sent, free of charge, upon request to the Editor, Miss Helen Lorraine, 5212 Sylvan Road, Richmond 25, Virginia.

On Thursday, June 22, 1950, the **Veterans Administration** opened its Exhibit of Prosthetic and Sensory Aids, and Research and Development Center, at the New York Regional Office, 252 Seventh Avenue, New York City.

To this permanent prosthetic center may come veterans and others facing serious or unique problems concerning the prostheses they wear. Inventors, manufacturers, researchers, and students also will have access to the library and testing and development laboratories, as well as to the exhibit itself, as a source of information and helpful guidance.

Readers of *The Journal* who have had dealings with DePuy Manufacturing Company will regret that Mr. H. Herschel Leiter, president of the Company, died on May 9. Mr. Leiter was best known for his work in the advancement of splints,—not only his own inventions, but improvements developed through cooperation with leading orthopaedic surgeons to make available the equipment needed for the most advanced techniques in the treatment of fractures. Mr. Leiter set the highest standards for the work of his organization.

The Kappa Delta Award for Research in Orthopaedic Surgery, a prize of one thousand dollars, donated by the Kappa Delta Sorority, is awarded annually by **The American Academy of Orthopaedic Surgeons** for the best research done in orthopaedic surgery or a related scientific field by an individual in the United States. The second award, for the year 1950, will be presented at the Eighteenth Annual Convention of the Academy in Chicago, January 31, 1951. Researchers interested are requested to secure further information from Dr. R. Beverly Raney, Duke Hospital, Durham, North Carolina, Chairman of the Award Committee for 1950.

The Annual Convention of the **National Society for Crippled Children and Adults** will be held October 26, 27, and 28, 1950, at the Stevens Hotel, Chicago. Marking twenty-nine years of service for the Society, the Convention will feature prominent authorities working in the field of the disabled, who will present latest developments in the treatment, training, and care for the nation's handicapped children and adults.

Delegates from the more than 2,000 state and local affiliates of the National Society in the forty-eight states, District of Columbia, Alaska, Hawaii, and Puerto Rico will be in attendance to obtain up-to-date knowledge of the National Society's three-point program of education, research, and direct services.

The Ninth Annual Meeting of the **Sociedade Brasileira de Ortopedia e Traumatologia** will be held at the Hospital Santa Casa, São Paulo, Brasil, August 22 through 26, 1950.

The principal subjects of discussion will be "Treatment of Fractures of the Shaft of the Femur", with Dr. M. Lazareschi, of São Paulo, and Dr. M. Weinberger, of Rio de Janeiro, presenting official reports, and "Osteotomies", with Prof. Dagmar Cháves, of Rio de Janeiro, and Dr. E. Navajas, of Santos, leading the discussion. Clinical demonstrations will be presented in the orthopaedic clinic of the Hospital das Clinicas da Universidade de São Paulo, by Prof. Godoy Moreira, and in the orthopaedic clinic of the Santa Casa, by Prof. D. Define.

Among the guests of honor will be Dr. H. W. Meyerding, of Rochester, Minnesota, U.S.A., Prof. José Valls and Dr. Carlos Ottolenghi from Buenos Aires, and Dr. José Bado from Montevideo.

The President of the Society, Dr. Renato da Costa Bomfim, of São Paulo, extends an invitation to orthopaedic surgeons of North America to attend this meeting

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The **Washington Orthopaedic Club** was host to the Baltimore Orthopaedic Club at their annual combined meeting on April 22 at the Army and Navy Club. The scientific program included the following subjects:

The Use of Myanesin (Tolserol) with and without Tubocurarine in Low-Back Pain.
Eugene G. Lipow, M.D.
Discussion: David L. Filtzer, M.D.

Retrosternal Dislocation of the Clavicle.
Allen M. Ferry, M.D.
Discussion: Harold R. Bohlman, M.D.

The Suction-Socket Prosthesis.
Everett J. Gordon, M.D.
Col. A. W. Spittler, M.C.
Discussion: Milton J. Wilder, M.D.

Posterior Dislocation of the Shoulder.
Paul O'Donnell, M.D.
Discussion: E. David Weinberg, M.D.

The Chronic Arthritis of Reiter's Disease.
Maurice Herzmark, M.D.
Discussion: Robert W. Johnson, Jr , M.D.

Albers-Schönberg Disease.
Alfred E. Jackson, M.D.
Discussion: H. Alvan Jones, M.D.

Bone Diseases in the Early American Indian.
William Tobin, M.D.
Daniel Regan, M.D.
Discussion: T. D. Stewart, M.D., Curator of Physical Anthropology, United States National Museum.

In most cases, the first speakers represented the Washington Club, and the leaders of the discussions, the Baltimore Club.

The **Third Annual Symposium on Orthopaedic Appliances** will be held at Mellon Institute during the week of September 18, 1950. This Symposium will again be a cooperative undertaking of the Department of Orthopaedic Surgery of the University of Pittsburgh's School of Medicine and the Sarah Mellon Scaife Foundation's Multiple Fellowship on Orthopaedic Appliances at Mellon Institute.

In contrast to the first and second symposia, the 1950 sessions will be devoted largely to clinical, laboratory, and shop demonstrations and discussions. Included will be several formal lectures by nationally recognized authorities who will discuss bracing in the treatment of back conditions, cerebral palsy, congenital deformity and various problems of rehabilitation and training of the handicapped. The Symposium will be open by invitation to orthopaedic surgeons, physical therapists, makers of orthopaedic appliances, and other workers in the field of rehabilitation.

A worth-while program of lectures, surgical clinics, brace-making exhibits, engineering demonstrations, and discussions has been planned for the five-day period.

Inquiries concerning requirements for attendance and further information about the Symposium should be addressed to The Orthopaedic Appliances Fellowship, Mellon Institute, 4400 Fifth Avenue, Pittsburgh 13, Pennsylvania.

The Tenth Anniversary Celebration of the **Alfred I. du Pont Institute of the Nemours Foundation** was held in Wilmington, Delaware, on June 17. An interesting program was planned for the morning and afternoon sessions, including the following subjects:

Morning Session

Howard A. Rusk, M.D., Chairman.

Ten Years of the Care and Treatment of Crippled Children.
A. R. Shands, Jr., M.D., Wilmington, Delaware.

Physical Medicine in Europe with Particular Reference to the Care of the Crippled Child.
Frank H. Krusen, M.D., Rochester, Minnesota.

Occupational Therapy in a Crippled Children's Hospital.
Mrs. Winifred C. Kahmann, Indianapolis, Indiana.

The Education of the Crippled Child, A Report on the Recent International Conference in Geneva, Switzerland, on the Educational Problems of the Orthopaedically Handicapped Child.
Mr. Lawrence J. Linck, Chicago, Illinois.

Basic and Applied Research in a Crippled Children's Hospital.
Lee E. Farr, M.D., Upton, Long Island.

The Place of the Parents in the Care of the Handicapped Child.
Mrs. William G. Hamm, Atlanta, Georgia.

Afternoon Session

George E. Bennett, M.D., Chairman.

Speech Problems in the Handicapped Child.
Harold Westlake, M.D., Chicago, Illinois.

The Organization of a Model Cleft-Palate Clinic.
Herbert K. Cooper, M.D., Lancaster, Pennsylvania.

Cerebral Palsy, A Cause of Crippling in Childhood.
W. M. Phelps, M.D., Baltimore, Maryland.

The Emotional Aspects of Crippling in Childhood.
Leslie B. Hohman, M.D., Durham, North Carolina.

The Closing Address was given by Dr. Francis P. Gaines, President of Washington and Lee University, Lexington, Virginia.

Dr. Leo Mayer has recently returned from a trip to Israel where he had been invited by the Ministry of Health to participate in their Rehabilitation Program. He held a series of diagnostic clinics in Tel Aviv, Jerusalem, Haifa, and other centers; operated on a carefully selected group of cases in order to illustrate recent advances in orthopaedic technique; and delivered six lectures dealing with orthopaedic topics. He has written us a brief summary of his impression of Israel:

"This, the youngest nation of the United Nations, gives the impression of remarkable virility and enterprise. Despite the fact that the citizens came from more than forty different countries, they are united by a healthy spirit of nationalism,—healthy, because it results in a determination to defend themselves against the hostile countries which surround them on all sides, and because of their determination to keep their doors wide open as a haven for the oppressed Jews of the world.

"Since Israel declared itself an independent nation in May 1948, there has been an influx of 400,000 immigrants,—more than 60 per cent. of the original population of the country. To house and feed this vast number of newcomers, the Israeli have instituted a rigid austerity program, denying themselves all but the simplest food and taxing themselves to the hilt. Thanks to their efforts, more than 300,000 of the immigrants have already been placed in their own homes and have become productive citizens. There remain in the camps, however, approximately 90,000, chiefly from Yemen and North Africa. A new influx is expected during the coming year.

"I had the opportunity to meet President Weitzman and four members of the Israeli Cabinet. These leaders impressed me by their simplicity and unselfishness, and by their devotion to their work. The Foreign Minister changed his name from *Shertok* to *Sharett*, which means 'servant'. This is to me typical of the leaders of Israel; they are acting as 'servants of the people'. One has the feeling of an enthusiastic democracy, with equal opportunity for all."

SOCIEDAD LATINO-AMERICANA DE ORTOPEDIA Y TRAUMATOLOGÍA

Two years ago, a group of prominent orthopaedic surgeons from different Latin-American countries gathered at Mexico City, and the *Sociedad Latino-Americana de Ortopedia y Traumatología* was organized. Dr. Juan Farill, of Mexico City, was elected President of this organization.

The First Congress of the Society will take place December 8 to 17, 1950, at Montevideo (Uruguay), Buenos Aires (Argentina), and Mar du Plata, the exclusive summer resort near both cities. Dr. Alberto Inclán, of Havana, is President of this Congress. He personally, and Dr. Juan Farill, President of the Society, extend a most cordial invitation to members of The American Orthopaedic Association and the Canadian Orthopaedic Association to attend this First Congress.

The program includes the following subjects:

Arthrodesis of the Hip.

Dr. F. E. Godoy Moreira, Brasil; Dr. José Valls, Argentina; Dr. Rolfi D. Vázquez, Uruguay.

Discussion: Dr. Oscar Guzmán del Villar, Peru;
Dr. Luís A. Weber, Argentina.

Traumatic Lesions of the Elbow.

Dr. Renato da Costa Bomfim, Brasil; Dr. Teodoro Gebauer, Chile; Dr. Juan Farill, Mexico; Dr. Jorge de Romaña, Peru.

Discussion: Dr. Domingo Define, Brasil;
Dr. Zapato Arinez, Bolivia.

Symposia will be held on the following topics:

Low-Back Pain and Sciatica.

Dr. Alberto Croquevielle, Chile; Dr. Rodolfo Ferré, Argentina; Dr. Roberto Olmedo, Paraguay; Dr. Orlando Pinto de Souza, Brasil.

Moderator: Dr. Fortunato Quesada, Peru.

Club-Foot.

Dr. Polo Velazco, Mexico; Dr. Marcelo Gamboa, Argentina; Dr. Pedro Toledo Sánchez, Cuba; Dr. Carlos Urrutia, Chile.

Moderator: Dr. José A. Piqué, Argentina.

Giant-Cell Tumors.

Dr. Alfaro, Panama; Dr. Aquile de Araujo, Brasil; Dr. Fritz Mondolfo Sivano y Schajovicz, Argentina.

Moderator: Dr. José Ignacio Tarafa, Cuba.

Tuberculosis of the Hip. Results of Surgical Treatment.

Dr. Guillermo Allende, Argentina; Dr. Bonilla, Ecuador; Dr. Enrique Botero-Marulanda, Colombia; Dr. Dagmar Chávez, Brasil; Dr. Jorge Figarella, Venezuela.

Moderator: Dr. Pinheiro Campos, Brasil.

Fractures of the Neck of the Femur.

Dr. José Luís Bado, Uruguay; Dr. Luís J. Petracchi, Argentina; Dr. Edmundo Souza Batalha, Brasil; Dr. Luís J. Iglesias de la Torre, Cuba.

Moderator: Dr. Godoy Moreira, Brasil.

The Bone Bank.

Dr. Herbert Cagnori, Uruguay; Dr. Alberto Inclán, Cuba; Dr. José Sgrosso, Argentina; Dr. Velasco Zimbron, Mexico.

Moderator: Dr. José Londres, Brasil.

Courses will be given on the following:

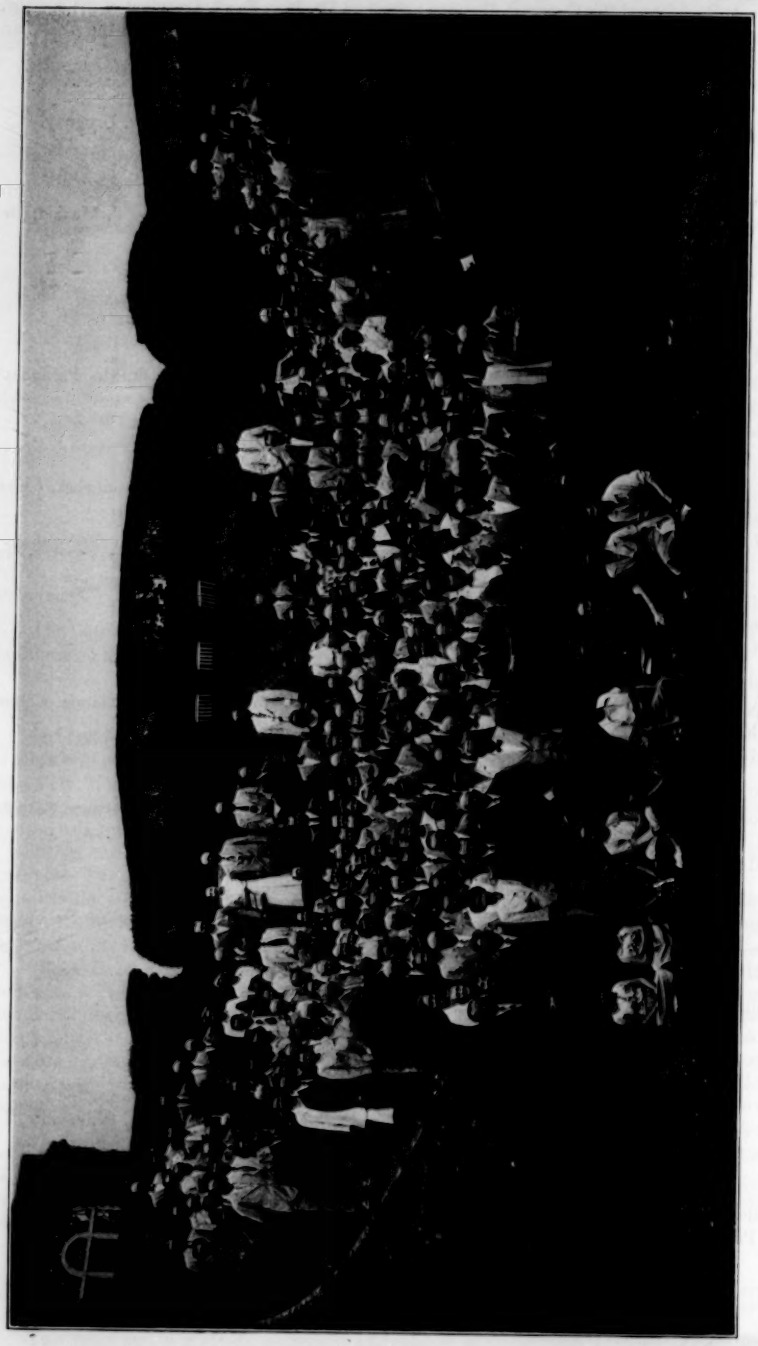
Pathology of Bone Tumors. By Dr. Fritz Schajovicz and Dr. Jorge E. Valls.
Compound Fractures. By Dr. Carlos E. Ottolenghi.
Bone Dystrophies. By Dr. Oscar Marottoli and Dr. Domingo Musculo.
External Fixation of Fractures. By Dr. José Manuel del Sel and Dr. Alfonso Montagne.
Some Aspects of Hand Surgery. By Dr. Felipe Alarcón Oleaga and Dr. Pedro V. Pedemonte.

The audio-visual sessions have been organized by Dr. Oswaldo Pinheiro de Campos, of Brasil.

The officers for this Congress are:

President: Dr. Alberto Inclán;
Vice Presidents: Dr. José Luís Bado;
Dr. José Valls;
General Secretaries: Dr. Carlos B. Ottolenghi;
Dr. Domingo Solfi Vázquez;
Treasurer: Dr. Herbert Cagnoli.

The address of the General Secretary of the Society is Dr. José Luís Bado, Institute de Traumatología, Montevideo, Uruguay.



Members and Guests of
The American Orthopaedic Association
attending the Annual Meeting held at
The Cavalier, Virginia Beach, Virginia
May 23, 24, 25, and 26, 1950.

THE AMERICAN ORTHOPAEDIC ASSOCIATION

The Sixty-Third Annual Meeting of The American Orthopaedic Association was held at The Cavalier, Virginia Beach, Virginia, on May 23, 24, 25, and 26, under the presidency of Dr. Robert W. Johnson, Jr.

On Monday, May 22, a Clinical Day was provided in Baltimore by the members of the Association in that city. Dr. I. William Nachlas was in charge of the program. The morning session was conducted at Johns Hopkins Hospital and the afternoon session was held at The Children's Hospital School, where luncheon was served.

The clinical presentations were as follows:

*Morning Session**, The Johns Hopkins Hospital

An Unusual Fatty Tumor. E. D. Weinberg, M.D.
Danlos-Ehlers Syndrome. G. Bauer, M.D.
Fracture of the Anterior Process of the Calcaneus. M. Gellman, M.D.
Studies on the Mechanism of Calcification. J. E. Howard, M.D., and P. S. Rubin, M.D.
Vasomotor Disturbances in Injuries of the Extremities. I. R. Trimble, M.D.
Some Unusual Operative Experiences. G. E. Bennett, M.D.

Afternoon Session, The Children's Hospital School

Posture. A Film. Henry O. Kendall and Florence P. Kendall.
Operative Correction of Pectus Excavatum. M. M. Ravitch, M.D.
End Results of Subtalar Arthroereisis. M. J. Wilder, M.D., and R. Abrams, M.D.
Arthrogryposis Multiplex Congenita in Twins. J. W. Hillman, M.D., and J. Johnson, M.D.

An interesting scientific program for the Meeting at Virginia Beach had been provided by the Program Committee, Dr. Joseph A. Freiberg, Chairman, as follows:

Tuesday, May 23

Afternoon Session

Diamond-Shaped Iliac Grafts for Non-Union of the Tibia.
Harry C. Blair, M.D., Portland, Oregon.
Discussion: Edward L. Compere, M.D., Chicago, Illinois;
J. Albert Key, M.D., St. Louis, Missouri;
John Royal Moore, M.D., Philadelphia, Pennsylvania;
H. Page Mauck, M.D., Richmond, Virginia.

Experience in Intramedullary Nailing of Long Bones with Report of Fifty Cases.
Colonel Oral B. Bolibaugh, M.C., San Francisco, California;
Colonel Vinnie H. Jeffress, M.C., San Francisco California (by invitation);
Major Michael J. Hitchko, M.C., San Francisco, California (by invitation).
Discussion: J. E. M. Thomson, M.D., Lincoln, Nebraska;
Harold A. Sofield, M. D., Chicago, Illinois;
Harry Romney, M.D., Havana, Cuba;
J. Albert Key, M.D., St. Louis, Missouri;
Paul B. Steele, M.D., Pittsburgh, Pennsylvania;
Hugh Smith, M.D., Memphis, Tennessee;
Leo Mayer, M.D., New York, N. Y.

A Preliminary Report on Subtrochanteric Osteotomy and Spline Fixation of Certain Hip-Joint Disabilities.
David Bosworth, M.D., New York, N. Y.;
Mather Cleveland, M.D., New York, N. Y.;
A. Della Pietra, M.D., New York, N. Y. (by invitation).
Discussion: Edwin F. Cave, M. D., Boston, Massachusetts;
Paul C. Colonna, M.D., Philadelphia, Pennsylvania;
James Dickson, M.D., Cleveland, Ohio;
M. N. Smith-Petersen, M. D., Boston, Massachusetts;
Mather Cleveland, M.D., New York, N. Y.

* Alternative Morning Program, Rounds with Dr. W. M. Phelps at Children's Rehabilitation Institute.

Gradual Subluxation of the Cervical Spine.
J. G. Kuhns, M.D., Boston, Massachusetts.
Discussion: Raymond E. Lenhard, M.D., Baltimore, Maryland;
Frederick A. Jostes, M.D., St. Louis, Missouri.

WEDNESDAY, MAY 24

Morning Session

The Surgical Management of Chronic Osteomyelitis by Saucerization, Primary Closure, and Antibiotic Control. Preliminary Report on Use of Aureomycin.
Joseph Buchman, M.D., New York, N. Y.;
John E. Blair, Ph.D. (by invitation).
Discussion: Guy A. Caldwell, M.D., New Orleans, Lousiana;
J. Albert Key, M.D., St. Louis, Missouri;
Louis G. Howard, M.D., Boston, Massachusetts;
G. E. Haggart, M.D., Boston, Massachusetts;
Frank D. Dickson, M.D., Kansas City, Missouri.

Anatomy and Physiology of Club Feet with Suggestions for Their Correction.
Steele F. Stewart, M.D., Honolulu, Hawaii.
Discussion: Walter Blount, M.D., Milwaukee, Wisconsin;
James Dickson, M.D., Cleveland, Ohio;
J. R. Moore, M.D., Philadelphia, Pennsylvania;
C. W. Peabody, M.D., Detroit, Michigan;
Beckett Howorth, M.D., New York, N. Y.

Scoliosis: Its Treatment by Directed Growth Control.
William Nachlas, M.D., Baltimore, Maryland;
Jesse N. Borden, M.D., Baltimore, Maryland (by invitation).
Discussion: John R. Moore, M.D., Philadelphia, Pennsylvania;
Arthur Steindler, M.D., Iowa City, Iowa;
John R. Cobb, M.D., New York, N. Y.;
A. B. LeMesurier, M.D., Toronto, Ontario, Canada;
Paul B. Steele, M.D., Pittsburgh, Pennsylvania.

The General-Adaptation Syndrome and the Diseases of Adaptation — With Special Reference to the Clinical Use of ACTH and Cortisone.
Hans Selye, M.D., Montreal, Canada (by invitation).

An Analysis of the Motions of a Normal Hip Joint as Compared with the Motion after Mold Arthroplasty. Sources of Error in Reconstruction.
M. N. Smith-Petersen, M.D., Boston, Massachusetts.
Discussion: George Bennett, M.D., Baltimore, Maryland;
Ralph Ghormley, M.D., Rochester, Minnesota.

THURSDAY, MAY 25

Morning Session

Collison Metallic Femoral Head.
Leonard T. Peterson, M.D., Washington, D. C.
Discussion: Robert Jaenichen, M.D., Saginaw, Michigan (by invitation);
Leo Mayer, M.D., New York, N. Y.;
J. E. M. Thomson, M.D., Lincoln, Nebraska;
Paul B. Steele, M.D., Pittsburgh, Pennsylvania;
Alan DeF. Smith, New York, N. Y.;
Harold Bohlman, M.D., Baltimore, Maryland.

Experimental and Clinical Use of Oxidized Cellulose and Cortisone in the Prevention of Bone and Fibrous-Tissue Formation.
Frank E. Stinchfield, M.D., New York, N. Y.
Discussion: Edgar M. Bick, M.D., New York, N. Y.;
Dallas Phemister, M.D., Chicago, Illinois;
J. Albert Key, M.D., St. Louis, Missouri;
William D. Ewing, M.D., Louisville, Kentucky.

The Viability of Various Types of Bone Grafts as Determined by Radio-Active Phosphorus.
J. Albert Key, M.D., St. Louis, Missouri;
Richard T. Odell, M.D., St. Louis, Missouri (by invitation);
C. Barber Mueller, M.D., St. Louis, Missouri (by invitation).

Discussion: C. Howard Hatcher, M.D., Chicago, Illinois;
H. Herman Young, M.D., Rochester, Minnesota.

Presidential Address.
Robert W. Johnson, Jr., M.D., Baltimore, Maryland.

FRIDAY, MAY 26

Morning Session

Subastragalar Arthrodesis with Slot Grafts for Correction of Paralytic Flat Feet in Young Children.
David Grice, M.D., Cambridge, Massachusetts (by invitation).
Discussion: J. H. Kite, M.D., Atlanta, Georgia;
William T. Green, M.D., Boston, Massachusetts;
C. W. Peabody, M.D., Detroit, Michigan;
Leo Mayer, M.D., New York, N. Y.;
J. Albert Key, M.D., St. Louis, Missouri;
H. Relton McCarroll, M.D., St. Louis, Missouri.

Action of Muscles in Health and Disease.
Verne T. Inman, M.D., San Francisco, California;
LeRoy C. Abbott, M.D., San Francisco, California;
John B. deC. M. Saunders, M.D., San Francisco, California (by invitation).
Discussion: Arthur Steindler, M.D., Iowa City, Iowa;
Joseph S. Barr, M.D., Boston, Massachusetts;
Edgar M. Bick, M.D., New York, N. Y.;
J. Albert Key, M.D., St. Louis, Missouri;
LeRoy C. Abbott, M.D., San Francisco, California.

Vitamin-Resistant Rickets.
H. E. Pedersen, M.D., St. Louis, Missouri (by invitation);
H. Relton McCarroll, M.D., St. Louis, Missouri.
Discussion: G. E. Haggart, M.D., Boston, Massachusetts;
William T. Green, M.D., Boston, Massachusetts;
Edwin W. Ryerson, M.D., Chicago, Illinois;
Beckett Howorth, M.D., New York, N. Y.

Wedge Excision of Congenital Vertebral Defects in Infancy.
Philip Wiles, F.R.C.S., London, England (by invitation).
Discussion: Edward L. Compere, M.D., Chicago, Illinois;
Alan DeF. Smith, M.D., New York, N. Y.;
John R. Moore, M.D., Philadelphia, Pennsylvania.

Executive sessions were held Tuesday noon and Friday noon.

The Annual Banquet was held on Thursday evening, May 25. Dr. Detlev W. Bronk, President of Johns Hopkins University, was guest speaker.

Dr. James Spencer Speed of Memphis, Tennessee, is President of The American Orthopaedic Association for the year 1950–1951. At the Executive Session on Friday, May 26, the following officers, members of committees, and delegates were elected:

Officers

President-Elect: Fremont A. Chandler, M.D., Chicago, Illinois.
Vice-President: Herman C. Schumm, M.D., Milwaukee, Wisconsin.
Secretary: C. Leslie Mitchell, M.D., Detroit, Michigan.
Treasurer: Frank D. Dickson, M.D., Kansas City, Missouri.

Committee Members

Membership Committee: R. Beverly Raney, M.D., Durham, North Carolina.
Program Committee: Keene O. Haldeman, M.D., San Francisco, California.
Research Committee: C. Howard Hatcher, M.D., Chicago, Illinois.

Delegate to the American College of Surgeons

J. Albert Key, M.D., St. Louis, Missouri.

Representatives on The American Board of Orthopaedic Surgery

Rufus H. Alldredge, M.D., New Orleans, Louisiana.
William M. Roberts, M.D., Gastonia, North Carolina.

The following were elected to active membership in The American Orthopaedic Association:

William H. Bickel, M.D., Rochester, Minnesota;
John J. Fahey, M.D., Chicago, Illinois;
Charles J. Frankel, M.D., Charlottesville, Virginia;
George J. Garceau, M.D., Indianapolis, Indiana;
Walter C. Graham, M.D., Santa Barbara, California;
Robert J. Joplin, M.D., Boston, Massachusetts;
J. Vernon Luck, M.D., Los Angeles, California;
Harry D. Morris, M.D., New Orleans, Louisiana;
John R. Norcross, M.D., Chicago, Illinois;
Benjamin E. Obletz, M.D., Buffalo, New York;
Frederick R. Thompson, M.D., New York, N. Y.;
Vernon P. Thompson, M.D., Los Angeles, California;
Harry Winkler, M.D., Charlotte, North Carolina.

The next Congress of the **International Society of Orthopaedic and Traumatic Surgery** will be held in Stockholm, May 21–25, 1951.

The two main subjects will be: (1) Avitaminosis and Bone Changes, with Dr. R. Zanoli of Italy and Dr. E. Rutishauser of Switzerland as the principal speakers; and (2) Low-Back Pain and Sciatica: Results of Treatment, with Dr. Joseph S. Barr, of Boston, Massachusetts, as the first speaker.

In addition, the members of the Association are invited to lecture on subjects of their own choice. The subjects of all lectures must be submitted to the Secretary of the Congress, Dr. Anders Karlen, Karolinska Institutets Ortopediska Klinik, Stockholm, before October 31, 1950.

A summary of the lecture, written in one of the five official languages of the Association, should at the same time be sent to the General Secretary, M. Jean Delchef, 34 Rue Montoyer, Brussels.

DISCUSSION

Legg-Perthes Disease

(*Continued from page 676*)

Crutches are not necessary, but where the condition is bilateral, we have used two braces with crutches. The results are excellent, although they necessarily depend upon how long after the onset of the process weight-bearing is discontinued. The child can live at home and go to school, and the treatment is economical and effective.

Dr. Maurice M. Pike (closing): I agree with Dr. Howorth that it would be ideal if these cases could all be seen immediately after the onset of the pathological process. Unfortunately, as Dr. Gill has emphasized, in most instances the disease process is well advanced before the symptoms are noted. I also agree that the treatment can be carried out at home. In most communities, home teaching is available under the direction of the Board of Education, so that schooling can be continued and therapy can be followed by the patient's own physical therapist, but the cooperation of the patient and the family is still necessary. Many times the family ceases to cooperate before the child does.

We believe that the Thomas ischial weight-bearing splint is a good thing. However, these children grow and, unless we watch closely, the leg either gets longer or pulls forward and weight-bearing results. Sometimes it can be adjusted before harm has been done. Our principle is non-weight-bearing. This paper describes one method of effecting it.

Book Reviews

MODERN TRENDS IN ORTHOPAEDICS. Edited by Sir Harry Platt, M.D., M.S., F.R.C.S. London, Butterworth and Co., Ltd., 45 shillings; New York, Paul B. Hoeber, Inc., 1950. $10.00.

Under the editorial supervision of Sir Harry Platt, a clear and concise presentation of modern trends in orthopaedics has been made possible in a book of just under 500 pages.

This valuable volume of fourteen essays meets a keenly-felt need for a concise and authoritative statement of up-to-date theory and method in the diagnosis and treatment of the injuries and diseases of the locomotor system. The work not only records recent developments, but imparts perspective. The teacher, surgeon, postgraduate student of orthopaedics, and the advanced undergraduate will find the book of such value that he will wish to include it in his library.

Each essay constitutes a chapter devoted to one of the major problems of orthopaedic surgery, such as "Fracture Treatment", "Tuberculosis of Bones and Joints", "Pyogenic Affections of Joints and Bones", "Congenital Deformities of the Spine and Limbs", "Scoliosis", "Injuries and Derangements of the Spinal Column", "Injuries of Muscles and Tendons", "Certain Vascular Lesions", "Paralysis", "Chronic Arthritis", "The Bone Dystrophies", *et cetera*.

Each chapter has been written by a well-known British orthopaedic surgeon whose extensive interest and experience make him especially well fitted to present the particular subject. Each is well done.

While the viewpoints expressed are distinctly British, the essayists have drawn freely from theory and practice in other countries. This seems especially true of American concepts and methods from which, in most instances, the best seems to have been selected.

The bibliographies are small but very carefully selected.

The format, illustrations, and printing are less handsome than in many British surgical books published during recent years. The publication is, however, very much less expensive.

UROLOGICAL ASPECTS OF SPINAL CORD INJURIES. George C. Prather, M.D. Springfield, Illinois, Charles C. Thomas, 1949. $3.75.

The proper management of the urinary tract is an exceedingly important part of the treatment of spinal-cord injuries. Past records indicate that the majority of such patients who survived the initial injury eventually succumbed to disease of the urinary tract. Until recent years, the neurosurgeon had been unable to cope with the urological complications, and the urologist paid them less than serious attention. This unfortunate situation was remedied by Munro, who appreciated the situation and provided meticulous urological care for his patients.

This monograph by Dr. Prather is good. For the first time, a urologist writes intelligently and interestedly about the urological care of patients with spinal-cord injuries. The author combines the statistics of others with his own generous experience in the treatment of these cases, and so provides a sound basis for his opinions. A difficult subject is covered well in a small volume. The physiology, anatomy, and innervation of the bladder are reviewed. Former and recent methods of treatment are compared. Treatment is described in understandable detail, and a suggested program for future treatment is outlined.

The difficulties which are involved in the care of patients with spinal-cord injuries are many. This monograph is strongly recommended for students, since it is short and easily read. It has breadth enough, however, to be valuable to the urologist, the orthopaedist, and the neurosurgeon, to guide them in the proper management of patients with spinal-cord injuries.

FRACTURES. Ed. 5. Paul B. Magnuson, M.D., F.A.C.S., and James K. Stack, A.B., M.D., F.A.C.S. Philadelphia, J. B. Lippincott Company, 1949. $7.00.

In this fifth edition of *Fractures*, much of the material has been rewritten. Standard procedures of handling acute fractures and reconstructive operations are included. More emphasis has been placed upon the management of compound, or open, wounds, and upon rehabilitation, based upon knowledge gained from World War II. A chapter of approximately one hundred pages on fractures of the skull and vertebral column and on injury to the central nervous system was written by Loyal Davis; a shorter chapter of about twenty-five pages, on physical therapy in the treatment of fractures, was contributed by John S. Coulter.

Stress is placed upon safe methods, and the book is written in a style suitable for general practitioners and general surgeons, rather than for the more highly trained bone and joint surgeons; consequently, some of the "safe" methods may not be the best ones in the hands of an expert, who is trained to do the more difficult procedures which in the end will give better results. It is gratifying to find condemnation of the use of the

Steinmann pin for skeletal traction, since it displaces bone and is frequently followed by the formation of ring sequestra, but it is somewhat surprising to note the advocacy of the Kocher manoeuvre, which can be unduly traumatic in reducing shoulder dislocations. Also, the use of prolonged skin or skeletal traction in the management of forearm fractures might be questioned by many surgeons, because it is well known that this method is usually an inefficient means of correcting and maintaining alignment of the fractured forearm bones.

This text will continue to be one of the worth-while standard works on fractures, and a reference book of this sort should be on the shelf of every doctor treating bone injuries. This generally simple and straightforward presentation is suitable for the undergraduate medical student as well.

THÉORIE ET PRATIQUE DE L'OSTÉOSYNTHÈSE. Robert Danis. Paris, Masson et Cie, 1949. 1100 francs.

The author does not accept the current opinion that bony union after a fracture is achieved through the formation of a callus. After a properly-done osteosynthesis, no periosteal or endosteal callus should ever be apparent on the roentgenograms. As a matter of fact, he considers the fracture callus as a pathological formation, development of which must be avoided.

Fractures are reduced by means of a fracture table, specially devised for the practice of osteosynthesis. The author describes many instruments that he finds useful in his operative procedures. He uses steel wire and two specially devised types of screws, one for the cortical bone and the other for the spongy bone. He also uses threaded pins and nails.

The osteosynthesis should produce and maintain constant pressure between the bone fragments. The metallic plates now in use often distract the bone fragments. To accomplish axial pressure at the fracture site, the author uses special plates. Although pressure between the bone ends may be obtained with his plate at the time of the operation, it is difficult to realize how this pressure can be maintained later, when the necrotic portion of the bone ends becomes absorbed. Double, long plates are applied to fractures of the femur. Bone grafts are used by the author in pseudarthrosis when there is loss of bone substance.

The last part of the book is devoted to a consideration of the treatment of fractures of the calcaneus, the ankle, the tibial plateau, the femur, the humerus, and the bones of the forearm. The author most often uses wire and nails for the treatment of fractures of the calcaneus. For fractures of the femoral neck, a four-flanged nail is used instead of the usual Smith-Petersen three-flanged nail.

This book may be of use to surgeons who favor the treatment of most fractures by means of open reduction and metallic fixation.

BRUCELLOSIS (UNDULANT FEVER). CLINICAL AND SUBCLINICAL. Ed. 2. Harold J. Harris, M.D., F.A.C.P. New York, Paul B. Hoeber, Inc., 1950. $10.00.

This is the second edition of Dr. Harris's book, very much expanded and "brought up to date". Like the first edition which appeared in 1941, it is based largely on the author's personal experience, gained almost entirely from private practice. The number of his patients has increased, in the interval, from 250 to about 700 and many of them have now been followed from five to fifteen years.

The overwhelming majority of these patients, unfortunately, are considered to have "chronic brucellosis". This diagnosis is usually arrived at after long and careful observation of the patient's symptoms and course and after compiling and correlation of all available laboratory evidence, no single part of which, by itself, could be considered as conclusively establishing the diagnosis. He has thus been able to include a large number of patients having undiagnosed chronic illnesses with bizarre and obscure symptoms, with or without fever, many of whom had been labelled psychoneurotic or who had been considered as having somatic disorders of unknown etiology. It is of interest, in view of the long experience of the author, that his patients include only a negligible number in whom the symptoms ascribed to chronic brucellosis began with an acute attack in which the diagnosis was established by isolation of the causative organism that both he and Dr. Walter M. Simpson, who contributed the foreword, consider to be the only definitive diagnostic procedure.

This fact must be borne in mind in evaluating the section on orthopaedic manifestations. Many conditions of obscure etiology are considered to be "due to or associated with brucellosis". They include acute, subacute, and degenerative myositis, "myotendonitis", bursitis, hydrarthrosis, arthralgia, and arthritis,—even rheumatoid arthritis and osteo-arthritis. The diagnosis in these cases is based, in the last analysis, on the symptomatic improvement which follows the use of graded doses of Brucella vaccines, a form of therapy which is discredited by other authorities in this field. Suppurative arthritis, osteomyelitis, and spondylitis, from which the causative organism has been isolated by culture, are, of course, also included; but they are not segregated, as they should be, because in them the diagnosis has been established beyond a reasonable doubt. The author is willing to ascribe many cases of neuralgia and neuritis to chronic brucellosis and, in the addendum, he appears anxious to embrace some cases of multiple sclerosis within his "specialty". It might be well to await more definite proof before lending credence to this concept.

The book is clearly printed on good paper and has a long bibliography of 742 titles. Those interested in this very important disease will certainly want to be acquainted with the author's concept of "chronic

brucellosis", and should read the evidence he has presented for believing that this disease is widely prevalent, in both "clinical and subclinical" forms.

THE SURGICAL TREATMENT OF FACIAL INJURIES. Varaztad Hovhannes Kazanjian, M.D., D.M.D., and John Marquis Converse, M.D. Baltimore, The Williams and Wilkins Company, 1949. $10.00.

Plastic and reconstructive surgery of the head and neck attracts surgeons with a variety of types of surgical background. The otolaryngologist is attracted because of problems in corrective surgery of the nose. The general surgeon may be attracted because of the problems of repair following radical surgical excision for carcinoma. The senior author of this book was attracted because of the dental problems related to war injuries of the jaws in World War I. *The Surgical Treatment of Facial Injuries* is largely a résumé of the personal experiences of the senior author during his long and distinguished career.

Of greatest interest are the chapters on fractures and deformities of the jaws and facial bones. Each group of fractures is considered from the point of view of anatomy, surgical pathology, examination and diagnosis, and treatment. The application of dental techniques to the general management of these fractures and deformities is profusely illustrated with clear line drawings, roentgenograms, and photographs. Some of the methods may seem complicated to the orthopaedic surgeon, but simpler methods, equally effective, are applicable in many of the conditions. The use of traction for displacement of the facial bones is of doubtful value because the malposition results, not from muscle pull, but from the blow itself. The authors discuss the use of external pin fixation of mandibular fractures, but rightly point out that "simpler procedures could have been used with greater assurance of achieving occlusial restoration".

Most of the remaining chapters deal with methods of treatment of congenital and traumatic deformities of the face and neck. Pedicled skin flaps, free grafts of skin and mucosa, and free grafts of dermis fat, fascia, cartilage, and bone are discussed. The authors present a variety of methods of shifting flaps in facial repairs, showing details of the technique and final results. However, one cannot fully agree with the use of flaps in burn contractures of the neck, because the normal contour of the neck is never so well restored as with free grafts.

In the chapter on maxillofacial prostheses, the authors describe the use of temporary appliances for support of bone or soft tissues during repair, and the permanent restoration of missing parts by appliances accurately cast to fit the abnormal contours and attached to glasses or a denture. Although even the best prostheses have much to be desired, they can be a splendid substitute for adequate surgery if circumstances necessitate their use. The authors emphasize: "The advantages of combining prostheses and surgery have been realized in recent years".

This book will be of interest to surgeons dealing with early and late repairs of deformities of the face. Many ingenious methods, perfected after years of experience, are illustrated, and should prove stimulating to any who are puzzled about the management of facial injuries.

HANDBOOK OF PHYSICAL MEDICINE AND REHABILITATION. SELECTIONS AUTHORIZED FOR PUBLICATION. The Council on Physical Medicine and Rehabilitation, American Medical Association. Philadelphia, The Blakiston Company, 1950. $4.25.

This is the fifth handbook published under the auspices of the Council on Physical Medicine and Rehabilitation, although the first with this exact title. It contains authoritative information on the known physical and physiological effects of procedures used in physical medicine, of particular value to students and specialists in this field. For those in the general practice of medicine and surgery, indications for the use of physical medicine in a broad variety of conditions are discussed by selected experts. Sufficient detail of technique is included to provide for adequate prescription or intelligent referral for physical medicine, but not enough for instruction of physical-therapy students. This new edition also includes chapters on occupational therapy and medical rehabilitation, in keeping with the expansion of these therapeutic techniques since the War.

Although this edition is the size of a textbook, it does not contain enough specific details of treatment and lacks sufficient illustrations to be substituted for one. It is recommended as a reliable source of information for general practitioners and surgeons and to give medical students the fundamentals of physical medicine.

ATLAS OF HUMAN ANATOMY. DESCRIPTION AND REGIONAL. Vol. II. Splanchnology, Angeiology, Nervous System, Organs of Sense. M. W. Woerdeman, M.D., F.R.N.A.Sc. Wageningen, N. V. Drukkerij Vada; Philadelphia, The Blakiston Company, 1950. $10.00.

This is the second book in a three-volume work, the first portion of which, dealing with osteology, arthrology, and myology, was published in 1948. Dr. Woerdeman, who is Professor of Anatomy and Embryology at the University of Amsterdam, is preparing this *Atlas* with the idea of presenting those details

most needed by the average medical student. He states: "In general I have omitted microscopical details, and included only those structures which can be seen with the naked eye or a small magnifying glass". Each plate is intended to be a true representation of an individual specimen.

In the section entitled "Digestive System", material on dental anatomy has been included, so that the work may also be used in schools of dentistry.

The quality of the illustrations is unusually good, and most of the drawings are shown as full-page plates. This volume has been well prepared and printed, and the set should be of considerable value.

INSTRUCTIONAL COURSE LECTURES, THE AMERICAN ACADEMY OF ORTHOPAEDIC SURGEONS. Vol. VI, 1949. Edited by Walter P. Blount, M.D., and Sam W. Banks, M.D. Ann Arbor, Michigan, J. W. Edwards, 1949. $8.00.

The wisdom of publishing the Instructional Courses given each year at the Annual Meeting of the Academy is attested by the increasing number of calls for the series.

Volume VI, which presents the lectures at the 1949 meeting, is larger than the previous ones. The Editors, Dr. Walter P. Blount and Dr. Sam W. Banks, have prepared an attractive volume, carefully edited. The illustrations lose some of their value in the offset process used; it may be questioned whether it is wise to include so many roentgenograms unless the book can be printed and a coated paper used.

The purpose of the volume is to make available to many the courses of lectures which only a few can attend. This purpose is being accomplished by the issuing of these volumes from year to year. The Editors are to be congratulated upon their fine work.

PROCEEDINGS OF THE FIRST CLINICAL ACTH CONFERENCE. Edited by John R. Mote, M.D. Philadelphia, The Blakiston Company, 1950. $5.50.

Late in 1946, The Armour Laboratories made available a preparation of ACTH (adrenocorticotrophin) to ascertain the properties of this hormone in the human being. Dr. George W. Thorn of Boston and his colleagues studied this preparation and found that it produced certain physiological and metabolic effects. These observations were confirmed by Dr. Fuller Albright and his associates at the Massachusetts General Hospital.

During the subsequent three years, different groups of workers to whom the limited supply of ACTH was made available carried out various studies in metabolic balance and adrenal cortical function; Dr. Edith B. Farnsworth of Chicago found that the status of nephrotic patients was altered by the hormone administration; Dr. Philip Hench of the Mayo Clinic discovered the effect of adrenal cortical stimulation in rheumatoid arthritis; and other workers studied its effects in a wide variety of disease processes.

The work had not been carried far enough to justify the publication of results; yet it was apparent that the experiences of one group would be helpful to other workers. The Armour Laboratories called a conference in Chicago on October 21 and 22, 1949, of actual investigators and their associates, to permit this exchange of information. There was ample opportunity for presentation of factual information and for informal discussion.

This volume is the record of this Conference. It will be of value to all workers in this field of research and to others who wish to be informed about their observations in adrenal cortical function in many disease syndromes. More convincing findings will appear in various publications when these workers can present more definite conclusions from their study.

THE ARTHROPATHIES. A HANDBOOK OF ROENTGEN DIAGNOSIS. Ed. 2. Alfred A. de Lorimier, M.D. Chicago, The Year Book Publishers, Inc., 1949. $7.00.

In the second edition of *The Arthropathies*, Dr. de Lorimier has kept essentially the same outline of material, but has done extensive rewriting and rearranging of the roentgenograms. Many of the illustrations are reproductions of those used in the first edition, published in 1943, but a series of wavy arrows were used on the earlier roentgenograms for identification purposes, and their removal makes the illustrations much clearer and more attractive. Many new figures have been added.

This handbook was based upon a series of lectures which Dr. de Lorimier delivered to officers at the Army Medical School and the Army School of Roentgenology, of which he was formerly Commandant, and the material is presented in the outline form which he used in teaching. However, a series of descriptive comments or generalizations have now been included, as well as sections giving summaries of roentgenographic findings and differential considerations. A short section has been added which deals with arthropathies of the temporomandibular joint, and throughout the text changes have been made in terminology to conform to general usage. For example, *osteochondritis* is used instead of *osteochondropathy*, and *degenerative joint disease* replaces *osteo-arthropathy*.

This is a careful revision, which adds greatly to the value of the book.

MEDICAL CLINICS ON BONE DISEASES. A Text and Atlas. Ed. 2. I. Snapper, M.D. New York, Interscience Publishers, Inc., 1949. $20.00.

To the orthopaedic student whose interest in the human skeleton extends beyond the range of gross deformity and body mechanics, whose scientific curiosity is aroused by the reaction of bone, apparently the most stable body tissue, to slight changes in metabolism, this volume must appeal as a source of information and as a stimulus to further study. The author has the gift of presenting a complicated, abstruse problem in such a form as to make it as fascinating as a work of fiction. Once begun, the book has to be read to the last page. The text is supplemented by forty-six plates on heavy photographic paper which reproduce roentgenograms and histological slides with the accuracy of the originals.

The first chapter deals with hyperparathyroidism (von Recklinghausen's disease). The reader is introduced to the pioneer work of Mandl and is then treated to a recital of Snapper's first case, that of a man of fifty-six who, when seen in 1929, had become completely incapacitated by generalized softening of the bones and marked muscular weakness. The diagnosis of osteomalacia was excluded by the patient's normal diet, which made avitaminosis D impossible. "Painstaking" palpation of the thyroid region disclosed the presence of a small tumor, about the size of a plum stone. The diagnosis of a parathyroid tumor was confirmed by the high serum calcium (23.6 milligrams per 100 cubic centimeters) and the low serum phosphorus (2.1 milligrams per 100 cubic centimeters). After the tumor had been removed, the patient made a striking recovery and lived contentedly until ten years later, when he died from a coronary thrombosis.

From the thyroid hyperfunction of von Recklinghausen's disease, the author passes naturally to parathyroid hyperplasia from other causes, such as that seen in experimental avitaminosis D, after biliary fistulae, and particularly in chronic renal insufficiency. He rejects the term "renal rickets" as misleading, since the lesion is not a lack of calcification, as in rickets and osteomalacia, but is a destruction of bone, associated with osteitis fibrosa, due to retention of acid substances. He agrees with Jaffe that acidosis is the main factor in the development of the bone lesions in chronic renal failure.

The chapter on rickets and osteomalacia is of particular interest because of Snapper's long sojourn in China, where he had unusual opportunity of studying the effect of avitaminosis D. He quotes the work of Miles and Feng who, as early as 1925, proved that the calcium balance in osteomalacia is always negative. This was not due to a low calcium intake, but to the deficient intake of a fat-soluble vitamin. Later this was shown to be vitamin D. Osteomalacia is frequent among Chinese women, very rare among the men.

He concludes that:

1. Foetal rickets may occur during the development of the foetus *in utero*, as a result of osteomalacia in the mother.

2. Rickets and tetany frequently occur even in the first few months of life, because the calcium and vitamin D content of the milk of osteomalacic mothers is extremely low.

3. Severe infantile rickets becomes relatively rare as soon as the children can crawl about, for then they play out of doors, in the sunny climate of North China.

4. Late rickets is occasionally observed in adolescents, particularly girls, living under abnormal conditions.

5. After marriage, osteomalacia becomes frequent in women, for their household duties limit their exposure to sunshine. Furthermore, the depletion of calcium in the skeleton during pregnancy and lactation becomes a major factor, in view of the extremely low intake of calcium and vitamin D in the food.

Other chapters deal with Osteoporosis, Paget's Disease, Lipoid Granulomatosis, Gaucher's Disease, Osteitis Fibrosa Disseminata, Neurofibromatosis of Bone, Multiple Myeloma, Skeletal Lesions in Leukemia, Bone Lesions in Hodgkin's Disease and Lymphosarcoma, and Bone Changes in the Hemolytic Anaemias.

The book brings the reader into intimate contact with the men who have helped to develop a new phase of medical history: Mandl, Cushing, Albright, Bauer, Jaffe, Lichtenstein, and others, who together with Snapper have shown that the bones reflect as in a mirror the minutest variation of the body metabolism.

OFFICE ORTHOPEDICS. Lewis Cozen, M.D., F.A.C.S. Philadelphia, Lea and Febiger, 1950. $5.00.

As stated in the preface, this little book was written for general practitioners, industrial surgeons, orthopaedic interns and residents, and pediatricians. It does not cover the subject in detail, but gives diagnostic criteria and therapeutic procedures familiar to the author through actual use.

There are three sections: The first covers techniques, including the use of plaster and other methods of immobilization, stellate ganglion and lumbar blocks, office physical therapy, the use of ethyl chloride spray (a procedure recommended by the author for many conditions), and prosthesis fitting.

The second section deals with diagnosis and treatment in a regional fashion, under such headings as the foot, the shoulder, the hand, *et cetera*.

The third section consists of chapters on various symptom complexes, giving the differential diagnoses and treatment of such conditions as club-foot, limp in the child, weakness of the arm or leg in an adult, and so forth. These discussions are of necessity very brief, especially when the condition is not amenable to office treatment. For example, only a very short paragraph is devoted to the muscular dystrophies, Brodie's

abscess, giant-cell tumor, and similar diseases. This seems proper in a book of this sort, but one would like a more detailed description of the treatment of club-foot, which is primarily an office procedure. In addition, the third section contains brief chapters on fractures, roentgen-ray, and the examination of orthopaedic cases for the law courts.

There is both a general bibliography and one for each chapter. The book is well illustrated with 156 line drawings and black-and-white reproductions.

The author states in the preface that at least one complete standard work on orthopaedic surgery should be available to the reader of this book. This is certainly true, for, as previously noted, some of the discussions are too brief to be of much value, particularly to those unfamiliar with orthopaedic problems. The reviewer cannot agree with all of the procedures advocated, as, for example, immobilizing the severely painful knee with hypertrophic arthritis in a long-leg plaster cast. An occasional omission is noted, notably in the chapter on the thigh and hip, where there is no discussion of acute trochanteric bursitis, although a reference to this condition is given. Nonetheless, the book has considerable merit and contains many useful hints as to diagnosis and treatment in the office or clinic. It will also orient the reader in the approach to orthopaedic problems, providing appropriate and up-to-date references.

PROCEEDINGS OF THE FIRST ANNUAL SYMPOSIUM ON ORTHOPEDIC APPLIANCES. Washington, D. C., The Orthopedic Appliances and Limb Manufacturers Association, 1950. $5.00.

In September 1948 the Mellon Institute of Industrial Research, in cooperation with the Department of Orthopaedic Surgery of the School of Medicine of the University of Pittsburgh and the Sarah Mellon Scaife Foundation arranged a conference at the Institute where orthopaedic surgeons met with physical therapists, brace-makers, and research workers in the adaptation of new alloys, new metals, and other types of material to the making of useful braces.

This book is actually a transcript of the proceedings of this first conference and demonstrates the benefit resulting from the opportunity for frank discussion of each other's problems. It is a valuable and authoritative text on orthopaedic appliances. Such an opportunity can only result in a better understanding of the common effort being made to help the handicapped with the best which can be made available in braces, supports, and prostheses.

The sponsorship of this Conference is quite in keeping with the purpose of Mellon Institute to carry out long-range research which will eventually benefit mankind.

THE 1949 YEAR BOOK OF ORTHOPEDICS AND TRAUMATIC SURGERY. Edited by Edward L. Compere, M.D., F.A.C.S. Chicago, The Year Book Publishers, Inc., 1950. $5.00.

Again Dr. Compere is to be congratulated upon his selection of articles from the year's literature which are of special interest. The book this year numbers over 450 pages; it is well printed and many illustrations have been reproduced from the original publications, adding to its attractiveness.

The compact little volume is of value not only to the orthopaedic surgeon, who may have missed some of the original articles, but also to workers in other fields who wish to keep in touch with the important developments in this specialty during the past year.

WORLD SURGERY 1950. Stephen A. Zieman, M.D. Philadelphia, J. B. Lippincott Company, 1950. $6.00.

As the title implies, this work is an ambitious undertaking for one man. The dedication is by Max Thorek, who states: "The year 1950, which marks the midpoint of the twentieth century, seems to be particularly appropriate as a time for measuring progress; and Dr. Stephen A. Zieman is not only a surgeon but an accomplished linguist and author equal to the task."

This book is evidently the result of wide reading by the author. It includes all branches of surgery with a chapter devoted to each. The author has selected from his reading interesting cases, new techniques which he considers practicable, and subjects which have had special attention in the surgical journals of the year. He has given concise abstracts of these articles with illustrations reproduced from the original journals.

Some will question the relative importance of the articles selected for abstract and will feel that these abstracts can hardly be called "world surgery" for 1950.

THROMBOSIS IN ARTERIOSCLEROSIS OF THE LOWER EXTREMITIES. Edward A. Edwards, M.D., F.A.C.S. Springfield, Illinois, Charles C. Thomas, 1950. $2.00.

This small volume, attractively printed and bound, is a worth-while addition to contemporary medical literature. The increasing longevity of the population makes the subject of thrombosis in arteriosclerosis more and more pertinent, and in calling attention to this fact the author has performed a useful service.

The book is divided into two parts. The first deals with the clinical picture, etiology, pathology, and treatment. The second presents case reports that illustrate, for the most part, the more severe aspects of the dis-

ease. Numerous photomicrographs illustrate the pathological findings and many line drawings show the various vessels involved in thrombosis and the resultant ischaemia.

It is the belief of the reviewer that many vascular surgeons would take issue with the author's reliance on lumbar sympathectomy in the acute phase of the thrombosis, on the grounds that any degree of hypotension might increase the propagation of the thrombus and that the action of anticoagulant therapy would be delayed. It has also been the experience of many in this field that intermittent venous occlusion is most effective in acute arterial insufficiency, contrary to the author's opinion.

However, with the understanding that in no field of surgery is opinion more diverse, this book is recommended to all in the field of vascular surgery and in particular to the general practitioner.

ILLUSTRATIONS OF SURGICAL TREATMENT. INSTRUMENTS AND APPLIANCES. Ed. 3. Eric L. Farquharson, M.D., F.R.C.S.(Edin.), F.R.C.S.(Eng.). Edinburgh, E. and S. Livingstone, 25 shillings; Baltimore, The Williams and Wilkins Company, 1949. $7.00.

In the author's own words, this book is designed to illustrate, by numerous photographs, practical methods of surgical treatment which are rarely covered in the textbooks of general surgery. The technique of blood transfusion, the closed treatment of fractures, and the identification of surgical instruments have been illustrated in detail.

This book should be valuable to students and house surgeons for quick reference and for familiarization with details of treatment pertaining to the subjects covered.

DIE WIEDERHERSTELLUNGS-CHIRURGIE. INSBESONDERE DIE VERWENDUNG DER ROLLAPPENPLASTIK (Reconstructive Surgery). Prof. Dr. Med. Karl-Ewald Herlyn. Stuttgart, Georg Thieme, 1949.

Although the title of this volume relates to reconstructive surgery, it is, as its subtitle indicates, primarily a treatise on skin plastics, with special emphasis upon the technique of the tubular pedicle flap. The superiority of this method over all other forms of skin plastics is presented. The technique of the procedure is described in great detail, with many excellent photographs to illustrate its application in the most distressing types of facial deformity. By far the largest portion of the work is devoted to plastic restoration of the nose and other facial defects. A relatively inconsequential discussion of the treatment of conditions which are of particular interest to the orthopaedic surgeon is inserted, obviously for the sake of completeness.

Despite the author's insistence that this form of reconstructive surgery falls within the purview of the general surgeon, his work will make its greatest appeal to those who are interested in cosmetic surgery rather than in other forms of functional reconstruction.

REHABILITATION, RE-EDUCATION AND REMEDIAL EXERCISES. Ed. 2. Olive F. Guthrie Smith, M.B.E., F.C.S.P. (Hon.), T.M.G. London, Ballière, Tindall, and Cox, 25 shillings; Baltimore, The Williams and Wilkins Company, 1949. $6.00.

This book is concerned primarily with the technical details of therapeutic exercise in the wide variety of conditions where exercise is an important part of rehabilitation. A unique aspect is the use of pulleys and springs to allow motion without the resistance of gravity for the weaker muscles. By varying positions, graded resistance can be applied according to progress. The mechanics of the individual exercises are well illustrated by line drawings and photographs, and the importance of exact technique in supervising exercises is rightly emphasized. Surprisingly, the second edition is identical with the first of seven years ago except for the addition of the appendix, containing short chapters on new procedures for chest conditions, hips, and spine injuries.

This is a useful text for physical therapists and doctors interested in the techniques of therapeutic exercise. Heat, massage, and electrotherapy are considered only briefly.

BONE AND JOINT RADIOLOGY. Emerik Markovits, M.D. New York, The Macmillan Company, 1949. $20.00.

Markovits, who has had many years of general radiological experience in Vienna and Budapest, and at the Steiner Cancer Clinic in Atlanta, Georgia, has attempted a brief and systematic tabulation of roentgenographic findings and related anatomical and pathological essentials in bone and joint diseases, with illustrations by diagrams and roentgenograms. The increasing popularity of this method of presentation, particularly at the student level, should make this a useful book. The subject is well covered, although masterly dissertations are lacking and much of the tabulation is condensed from old rather than modern orthopaedic concepts of the various diseases.

Part I contains sections on Anatomy and Physiology, Diseases of the Bones, Diseases of the Joints, and Diseases of the Muscles and of the Soft Tissues. Part II treats of the regions of the body, most of the areas

being covered briefly with the aid of diagrams. Many diagnostic problems are reduced to differential tables. Some of the roentgenographic illustrations are positive, some are negative, some are retouched, and many are excellent. The numerous diagrams are clear and helpful. The bibliography is voluminous, and the index is extensive and well prepared.

MODERN PRACTICE IN ANAESTHESIA. Edited by Frankis T. Evans, M.B., B.S., F.F.A.R.C.S., D.A. London, Butterworth and Company, Ltd., 15 shillings; New York, Paul B. Hoeber, Inc., 1949. $12.50.

This long book presents a summary of technique and practice of anaesthesia in Great Britain. Its thirty-eight chapters were written by twenty-four contributors who are specialists in various fields of anaesthesia and surgery. The first nine chapters are devoted to general subjects fundamental in the practice of anaesthesia, such as anatomy and physiology as related to anaesthesiology, the chemistry and pharmacology of anaesthetic agents, and a description of apparatus used in anaesthesia. Chapters ten to sixteen are devoted to various techniques and methods of anaesthetic administration. Certain specific problems of anaesthesia and surgery, such as postoperative care and treatment, anaesthetic emergencies, and posture in anaesthesia, are covered in chapters seventeen to twenty-two. In the remaining chapters, techniques in the administration of anaesthesia for various operative procedures and for patients presenting specific medical problems are described. Some of the topics covered are: anaesthesia in children, in old age, in the asthmatic patient, and anaesthesia for thoracic surgery, neurosurgery, and in obstetrics.

In a book surveying so wide a field, the treatment of each subject is necessarily brief; but in this case it is very comprehensive. Other sources must be consulted for exhaustive information. There are many illustrations, consisting of drawings, photographs, diagrams, and charts. The bibliography is conveniently arranged by grouping the pertinent articles at the end of each chapter.

Modern Practice in Anaesthesia presents a survey of present opinion and practice of anaesthesia in Great Britain, and for this reason some of the opinions and techniques differ from those in use in the United States. However; this divergence is not so wide as might be expected, and in basic matters there is general agreement.

The book is of particular interest to anaesthesiologists as a reference, because of the wealth of information it contains. It is also recommended for the libraries of surgeons and hospitals.

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